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# NATURAL HISTORY SURVEY

# OF MINNESOTA.

*The Nineteenth Annual Report, for the year 1890.*

From

N. H. WINCHELL,

State Geologist.

June 20, 1892

MINNEAPOLIS:
HARRISON & SMITH, PRINTERS.
1891.

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THE UNIVERSITY OF MINNESOTA.

MINNEAPOLIS, August 1, 1891.

*To the President of the University:*

DEAR SIR: The nineteenth annual report of the Geological and Natural History Survey of the state is herewith presented The larger part of the year was devoted to the preparation and the publication of the report on the iron ores of the state, embraced in Bulletin No. 6, which was finally issued in April, 1891. Into this (accompanying) report are gathered therefore various reports and papers that have accumulated in the progress of the survey, and some lists of specimens and publications, the printing of which will be a great convenience.

Respectfully submitted,
N. H. WINCHELL,
*State Geologist and Curator of the General Museum.*

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I.

# THE ELEMENTS OF A NEW METHOD OF CHEMICO-MICROSCOPIC ANALYSIS OF ROCKS AND MINERALS.

BY

DR. EMANUEL BORICKY.

(Archives of the Natural History Survey of Bohemia.)
(Vol. III. Part V.)
1877.

# NOTE.

This translation is the work of several persons. Begun in 1880 by the undersigned, it was suspended because of the urgency of other duties. It was resumed and carried on in 1887 by his daughter (now Mrs. F. N. Stacy), who in turn surrendered it to Miss Mary Blanchard, and by her in 1889 was finished the first English copy. It has recently been re-compared with the original by Mr. Herbert A. Wood, and a final revision and correction have been made by the writer.

In its present form this work will be constantly useful, not only to the collaborators of the survey in its examinations of the crystalline rocks, but to numerous petrographic students in America who do not have easy access to the original. The work of Boricky must always remain the headlight of any train of similar researches which may follow it—a train which has recently received some important accessions at the hands of Fouqué, Streng, Behrens and Renard. Messrs. Levy and La Croix have, lastly, arranged all of these methods in systematic order in their late work, *Les mineraux des roches* (Chapter VIII), and to this the student is referred.

N. H. WINCHELL.

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# INTRODUCTION.

Like a blazing meteor appeared the microscopic examination of minerals and rocks, in the horizon of inorganology. It created surprise by the sudden insight which it afforded into the internal nature of such minerals as had been subjected in vain to manifold hypotheses as to their differences of composition; it created surprise by its unexpected disclosures concerning the existence and origin of several crypto-crystalline rocks, of the nature of which erroneous ideas had been held for nearly a hundred years before; it illuminated many a crooked way which had been pursued in the science of lithology; but it also supplied means for judging of the genetic relationships of minerals and rocks, concerning which no one before ventured to speak without apprehension of much criticism. Therefore it gave rise to the hope that in it had been found the pathway which would lead to a sure knowledge of the mineral world, though concealed by an apparently impenetrable veil.

This hope, which must have taken possession of most mineralogists and geologists, seemed to come at once into realization, inasmuch as Vogelsang's *Philosophy of Geology*[1] and Zirkel's classic work[2] on the basalts followed, as well as Fischer's critical micro-mineralogical studies,[3] and the pioneer work of Sorby[4], for from this time the investigation of minerals and rocks sprang into active life. Microscope and lathe have been accepted and industriously employed as indispensible implements in the special researches of mineralogists and geologists. Numerous minerals have been examined in respect to their internal structure, by means of this new method of investigation; in various countries the investigation of larger and smaller rock-complexes was begun according to the new method, or individual kinds of rocks united under one name, were subjected to this new test. And in three years the scientific material increased so greatly that Zirkel, in the year 1873, found himself impelled to collect, and make accessible to his co-laborers, the scattered results of these researches on the constitution of rocks and minerals, by means of a splendid text book.[1]

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[1] Bonn, 1867.

[2] Bonn, 1870.

[3] Freiburg, 1869 and 1871.

[4] "On the microscopical studies of crystals, indicating the origin of minerals and rocks." *Quart. Journ. of the Geol. Soc. London*, *1858*. The microscope had already been used toward the end of the eighteenth century for the determination of isolated portions of crypto-crystalline rocks, by Dolomieu and Flerieu of Bellevue, but powdered rock only was the object under investigation. Thereupon the "schlemm process" with an investigation of the parts separated by "schlemm," was advocated by several French geologists. And this operation employed by Cordier (1815) on an enlarged scale received an important extension in a chemical treatment of the rock-powder. But the first crystalline thin sections which were submitted to the study of their inner structure appeared to be those of chiastolite, which Gerhard (according to Fischer's statement) had investigated. but only in reflected light. William Nicol made the first investigation of a thin section in transmitted light, and proposed a method for the display of thin sections; but a searching study of the nature of the inner structure of minerals was made first by David Brewster, who interested himself particularly concerning the petrological significance of fluid inclusions, and also recognized already the importance of microscopical investigation in polarized light. Brewster may be regarded as the true forerunner of Sorby, although microscopic investigations of minerals and rocks were undertaken before Sorby (by G. Rose, Scheerer, Jenzsch, Knope, von Rath and others)

But the scientific effort which showed itself in so rich a degree in the direction mentioned, led soon to the knowledge that in this path there were yet large gaps which must be filled up or at least bridged over, if a sure step forward would be taken. And in response to this generally felt need, Rosenbusch[2] hastened to place a practical guide in the hands of microscopic mineralogists and geologists, in order to place before their eyes, through the well ordered collection of diagnoses of the rock-bearing minerals, as far as at that time possible, a clear picture of the territory then known, and in an indirect way to make evident to them the uncertain spots and the gaps.

The next result of these endeavors was a work in the microscopic research of minerals and rocks, elevated high above the common level, which substantially enriched our knowledge in many directions, especially in respect to the micro-structure of rocks. It gave, however, occasion for many complications, in that often in place of positive results, only the old pillars of knowledge were overthrown and the insufficiency hitherto, of our means for new structures either public or private was shown, or in that only temporary buildings were erected upon the old foundations.

It would be reasonable—certainly in the light of the startling variety which Zirkel brought to notice in the basaltic rocks—to expect that there would be considerable difference also in other rocks heretofore united under one name, and that perhaps there would inevitably appear in respect of some kinds of rocks, a separation into many species, and in other kinds a union of species, but no one dreamed of the difficulties which arose concerning the degree of similarity which is necessary for the embracing of many groups of rocks under a common name, concerning the relations of geological, mineralogical, chemical and structural principles, upon which a natural system of rocks must be based in order to produce harmony. And the cause for these difficulties is, according to my opinion, to be found in general, in the constant extension of our petrological knowledge, in particular, however, in the deficiencies which are found in our microscopic methods, and which make their employment difficult or uncertain, often permitting only a subjective conception of the object under investigation.

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[1] The microscopic structure of minerals and rocks. Leipzig, 1873.

[2] Microscopic Physiography of the petrographically important minerals. Stuttgart, 1873.

Among these difficult (because incomplete) relations, Lassaulx undertook, in an excellent accurately compiled text-book,[1] devoted especially to the first work in the study of petrology, to bring the results of rock researches known up to that time into systematic order. But if one turn over the leaves of this text-book, suitable to any case, and go through the microscopic diagnosis of individual minerals and rocks, he will be led involuntarily to the above mentioned conclusion, that there is yet much to be accomplished upon the path leading to the right end, before a secure and easy advance towards it will be possible.

If we bear in mind the present standponti of microscopic rock research as it is set forth in the last mentioned text-book, and in those of Rosenbusch and Zirkel, we are obliged first of all to note great increments to the knowledge of the micro-structure of rocks, the micro-structure and other properties associated with it, of the rock-making minerals;[2] and also in the application of those optical properties which are connected intimately with the laws of individual systems of crystals, to the microscopical study of rocks there are (through the efforts

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[1] Elemente der Petrographie. Bonn, 1875.

[2] In regard to the knowledge of the micro-structure of minerals and rocks, Zirkel has unquestionably deserved the title of master. His works which appeared before the year 1873 are in his hand-book: "The Microscopic Properties of Minerals and Rocks, Excerped and Cited." And among his later works, those on the composition of Kersanton and the structure of Variolite (Ber. d. köngl. sächs. Ges. d. Wissensch. July 1875), and on Phyllit v. Recht im hohen Venn (Verh. d. naturh. V. d. preuss. Rhl. XXX. (1) should be mentioned. Also to Rosenbusch's above mentioned work in which his earlier works are noted, we have to add—besides his great work "Abhandlungen zur geolog. Specialkarte von Elsass-Lothringen," which I received from his friendly hand during the last few days—a valuable treatise "on the Composition and Structure of Granitic rocks," (Zeitschr. d. d. geolog. Ges. 1876) to which have been added two very important works by M. A. Michel Lévy (Structure microscopique des roches anciennes. Bull. soc. geol. France (3)III. 190-236, 1874. and Mémoire sur les dévers modes de structure de roches éruptives. Paris (Dunod, éditeur) 1875, relating to the same subject. Besides Sorby's already mentioned pioneer work, the following treatises of the same

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author should be noted; On the microsc. struct. of Mount Sorrel Syenite etc., Geol. and polytechn. Soc. of the West Riding of Yorkshire 1863; on the microsc. struct of the meteorites, (Proceed. Roy. Soc. London 1864); on the structure of Rubies, Sapphires. Diamonds and some other minerals (Proceed. Roy. Soc. London, 1869).

Contributions by other investigators have been made concerning the knowledge of the micro-structure of individual minerals and rocks, of a late date: Allport (Phon. vom Wolf-Rock. Geol. Mag. N. 84; Pechstein v. Aran, Geol. Mag., 1872, IX. Brit. Dolerite. Qaurt. J. of the Geol. Soc. London, 1874), Anger (Klast. Gest. Tschermack's Mineralog. Mitth., 1875), Artopé (Trachyte der Anden. Diss. Berlin, 1872), Behrens (Grünsteine. N Jahrb. 1871; Opale. Wien. Akad. 1871), Berteles (Ein neues vulk. Gest. Diss. Würzburg. 1874), Cohen (Geogn. petrogr. Skizzen a. Südafrika. N. Jahrb. 1874), Credner R. (Grünschiefer v. Hainichen in Sachsen. Schieferthone u. Thone. N. Jahrb. 1875), Dana (Trap Rocks of the Connecticut Valley. Proceed. of the Amer. Assoc. for the Adv. of Science. Hartford meeting, 1874, N. J., 1875), Dathe (Diabase. Dissert. Serpentine u. Eklogite d. saechs. Granulitgebietes. N. Jahrb., 1876). Doelter (Trachyte des Siebenbürg. Erzgeb.; Trachyte v. Tokaj-Eperies. Tschermak's Min. Mitth., 1874; Melaphyre Südost-Tirols Jahrb d. geol., Reichsanst. Wien, 1874, u. Tsch's Min. Mitth., 1875), Haarmann. Melaphyre, Diss. Leipzig, 1872), Hebenstreit (Urgest. d. nördl, Schwarzwaldes. Dissert. Würzburg. 1877). Emons (Phon. d. Veley u. Westerwaldes, N. J., 1875), Fouqué (les inclusions vitreuses renf. d. l. feldspaths des laves de Santorin; une ponc de Vesuv; les nodules à oligoklas des laves de Santorin; wollastonit, fassait, grenat des laves de Santorin; les laves des dykes de Thera. Comptes rendus de l'Acad. de Sc. Paris, 1873-1876), Geinitz (Grünsteine d.Saechs. Erzg. Tsch's Min. Mitth., 1876), Gümbel (Palæol. Eruptgst. d. Fichtelgeb. München, 1874. Geogn. Mitth. a. d. Alpen. Sitzgsb. d. k. bayr. Akad., 1877). Hull (Irische Granite. The Geol. Mag., N. J., 1874; Report on the Chem. Min. and Microsc. characters of the lavas of Vesuvius, from 1631-1868. N. J., 1876), Inostranzeff (Vesuvlaven v. Spt.. 1871, Maerz u. Apr., 1872; Kalksteine u. Dolomite, Tsch.'s Min. Mitth., 1872), Kalkovsky (Felsite u. Pechsteine Sachsens, Tsch.'s Min. Mitth., 1874; Felsitphorphyre b. Leipzig, N. J., 1875; Salit., etc., Tsch.'s Min. Mitth., 1875; Glimmertrapp v. Melzdorf, 1875; grüne Schiefer Niederschlesiens, N. J.. 1876; Einige Eruptgst. d. sæchs. Erzgeb. N. J. 1876), Kenngott (Obsidian, Petersburg. 1869 u. 1870), Koch (Donautrachytgruppe n. Budapest, N. J. 1877), v. Lassaulx (V. Gest. d. Auvergne, N. J. 1869-1872. Hemithrène d. Dep. Puy de Dôme, N. J. 1874. Eruptgst d. Vicentinischen, Z. d. d. geol. Ges. 1873), M. Lévy (Observ. sur. l' origine des roches eruptives. Variolite de la Durance, Acad.; Kersanton. Bull, de la soc. géol. de France, 1876), Liebe (Diabase d. Voigtlandes, N. J. 1870), Lossen (Porphyroide d. Harzes. N. J. 1877), Möhl (Sababurg; Scheidsberg b. Remagen; Bühl b. Weimar; Südwest. Ausläufer des Vogelsgeb; Basalte der rauhen Alp.; Bas. u. Phon. Sachsens; Bas. der preuss. Oberlausitz; Hauynbas. in Hessen; Gest. Thüringens. N. J. 1871-1875); Neminar (Erupgest, v. Banov in Mähren, N. J. 1877), Niedzwiedzki (Banater Eruptgst. Tsch.'s Min. Mitth. 1873) Petersen (Grünsteine, N. J. 1872), v. Rath (Monzoni. Bonn. 1875; Syenitgeb. v. Ditró, Trachytgeb. Hargitta., etc. Bonn. 1876. Geol. Reise n. Ungarn. Bonn. 1877), Rénard u. de la Vallíe Poussin (Mémoire sur les caractères min. et stratigr. de roches plutoniennes de la Belgique et de l' Ardenne Française. Acad. roy. Bruxelles, 1876), Rothpelz (Devon. Porphyroide Sachsens, N. J. 1877), Rutley (On some struct. in Obsidian, Perlite and Leucite. R. Microsc. Soc. 1876. Structure d. Feldsp., N. J. 1876), Sandberger (Neph. v. Katzenbuckel, N. J. 1869; Bas. u. Dolerite. N. J. 1870; Apatit im Olivinfels, Tachylyt v. Saesobühl, N. J. 1871; Kryst. Gest. Nassau's. Phys. u. Med. Ges. zu Würzb. 1873; Dolerit. Sitzb., d. k. bayr. Acad. 1873), Sauer (Phon. d. canarischen Inseln, N. J. 1876), Steenstrup (Om de Nordenskiöldske Jaernmasser og om Forekomsten af gedigen Jaern i Basalt Kjöbenhavn. 1876 u. N. J. 1887), Stelzner (Labradorit u. Pegmat. Berg-u. Hüttenm. Z. XXIX), Streng (Feldspathstudien, N. J. 1871; Porphyrite v. Ilefeld, N. J. 1875; Kryst. Gest. v. Minnesota, N. J. 1877), Törnebohm (Diabas u. Gabbrogest, Schwedens, N. J. 1877), Tschermak (Porphyrgest. Oesterreichs, Wien. 1869; Meteorit v. Lodran, Pogg. Ann. 1870. Meteorstein v. Goalpara. Wien, Acad. 1870; Pyroxen u. Amphibol, Min. Mitth. 1871. Meteoriten v. Stannern, Constantinopel, Shergotty u. Gosalpur, Min. Mitth. 1872), Umlauft (Thonschiefer, Lotos, Prag. 1876), Vogelsang (Flüssigkeitseinschlüsse in gewissen Min.

of Zirkel and Rosenbusch,) important advances to be noted.[1] There were indeed, important attempts made to determine individual species of certain groups of minerals, merely by means of optical properties. Tschermak[2] first alluded to the fact that the observation of pleochroism and light absorption rendered important service to the separation of individual branches of the amphibole and biotite groups; and later Descloizeaux showed how a member of the feldspar group can be identified with certainty by the determination of the position of the chief direction of oscillation in the known thin section of a feldspar by placing it in the maximum extinction of light between crossed Nicols[3].

Accordingly through excellent publications very important advances have been made in modern petrology by means of the employment of the morphological and optical properties of minerals; but the chemical laboratory which should reveal to us in the thin sections of the mineral its uniform and permanent characters by the results of certain tests seems—unfortunately for modern petrology—to refuse its aid. Noteworthy attempts have been made, it is true, in the latter direction and methods have been proposed for the determination of some rock-forming minerals in minute tests or thin sections, but these were either limited to a very few minerals or in their applications were of no special importance.

Indeed Zirkel, in his experiments upon the basalts has frequently proved the insolubility of the minerals in acids, by boiling the powdered rock in muriatic acid. By other investigators thin sections were boiled in muriatic acid or treated with cold muriatic acid; many important phenomena were

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Pogg. Ann. 1869; Krystalliten, hrsg. v. Zirkel. Bonn. 1874), Voldrich (Hercyn-Gneissformation, Jahrb. d. k. k. geol. Reichsanst. Wien. 1875), Vrba (Gest. Grönlands. Wien. Acad. 1875; Grünsteine, a. d. Adalbertl-Sch. v. Pribram, Oest. Z. f. Berg. u. Hüttenw. 1876), Zinckendrath (Kersanton v. Langeuschwalbach. Würzburg. 1875). In conclusion, I think that my works in relation to the Basalt, Phonolith and Melaphyrgesteine of Bohemia ought to be mentioned (Archiv. d. naturwiss. Landesdurchf. v. Böhemen. 1873, 1875 u. 1876).

[1] Very noteworthy are Rosenbusch's observations in his description of the new microscope for mineralogical and petrological researches. N. Jarhb, f. Min., 1876.

[2] Sitzb. d. k. Akad, d. W. in Wien, B. LIX. 7 Abth., 1869.

[3] Examen microscopique de l'orthose et des divers feldspaths tricliniques. Comptes rendus des séances de l'Academie des Sciences LXXXII,: seance du 1er Mai, 1876.

Memoire sur les propriétés optiques biréfringentes caracteristiques des quartre principeaux feldspaths tricliniques, et sur un procédé pour les distinguer immédiatement les unns des autres. Ann. de Chim. et Phys., IV.; 1875.—Memoire sur l'existence, les propriétés optiques et cristallographiques, et la composition chimique du microcline. nouvelle espèce de feldspath triclinique á base de potasse, suivi de remarques sur l'examen microscopique de l'orthose et de divers feldspaths tricliniques. Amn. de Chimie et de Phys., IX: 1876.

noticed, such as effervescence, separation of gelatinous silica, and the solution and removal of turbid secondary products.

Since, however, for the determination of the insolubility of a mineral in acids, no fixed law was decided upon, other than the carrying out of the same experiments under exactly similar conditions, different results were often obtained upon the same materials by different investigators, or the similar results were interpreted differently.[1] And the result was that, instead of establishing the conditions (specific gravity of the muriatic acid used, and length of treatment), under which the action of the acid should be exerted, distrust was aroused against this very reaction—which was susceptible of being used to a considerable extent, and successfully, especially upon thin sections—and thus its application became limited to the most necessary cases. So now, for example, this reaction is very little used for the approximate determination of individual members of that feldspar group, for which the comprehensive term, "plagioclase," is preferred.

Rosenbusch endeavored to introduce some operations, customary in analytical chemistry, such as the formation of precipitates, and their separation from the substances remaining in solution, by means of a filtering apparatus (under air pressure);[2] but his efforts appear to have had little result. Moreover the etchings which appear upon the various surfaces of minerals treated with dissolving reagents and which bear an intimate relation to the morphological character of the mineral, were hopefully alluded to; but,—although, except Leyden's[3] experiments upon quartz, Knopp's[4] upon xanthophyllite and Sohnke's[5] upon sodium chloride, a series of minerals[6] were investigated by Baumhauer in regard to their etchings—as to their value in petrology no decided advance has thus far been made.

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[1] In order to furnish an example, the following passage to be found on page 407, the 18th line from top, in Zirkel's Handbook, "The microscopical properties of minerals and rocks," may be cited. Through treatment with hydrochloric acid the plagioclase of diabase is strongly attacked and exhibits after this action on the polariscope no more lamellar banding. In a similar manner Senfter distinguishes the oligoklase nature of most feldspars, though he has observed (p. 692) of oligoklase, that by long digestion in hydrochloric acid it is as good as not affected.

[2] N. Jahrb. f. Min. etc. 1871. 914.

[3] Sitzb. d. k. Akad. d. w. in Wien XV. 1855.

[4] N. Jahrb. f. Min. 1872. 785.

[5] N. Jahrb. f. Min. 1875.

[6] The etchings on crystals. N. J. f. M. 1875. (190).
Upon potassium-mica, granite, cobalt-quartz. N. J. f. M. 1875. (192).
Upon magnesia-mica and epidote. N. J. f. M. 1875. (420).
Upon apatite and gypsum. N. J. f. M. 1875. (746).
Upon lithia-mica, turmaline, topaz, zinc-silicate. N. J. f. M. 1876, (1).
Upon adularia, albite, fluorite, and chlorides of natron. N. J. f. M. 1876. (602).

Very note-worthy also are those methods which have for their object the separation of individual minerals from the mixed crystalline rocks and their chemical analysis—such as Müller's separation of quartz and some silicates from each other by means of phosphoric acid hydrate,[1] Gümbel's "meal test"[2] and Fouque's method of separation of ferruginous portions from the non-ferruginous by means of a strong electro-magnet and by means of concentrated fluohydric acid[3]—but all these experiments are tedious and demand much material, which, when converted into powder, and the homogeneous mass of separated mineral particles is examined, admit no such minute microscopic observation as a mineral cut through in a thin section.

I consider Knopp's micro-chemical reaction[4] upon members of the hauyne family as quite simple and practicable. By this method for the first time a vaporous substance, (sulphur vapor) is converted into the constant character of a determined mineral of a thin section, viz., the blue color of a hauyne-like mineral and to the black of an iron holding mineral. Just as practical is the application of molybdate of ammonia for the proof of phosphates in thin sections, and especially for the separation of apatite from nepheline, which reaction was introduced by Streng.[5]

In conclusion Szabo's *Neue Methode, die Feldspathe auch in Gesteinen zu bestimmen*[6] deserves special notice, since by careful observation of certain experiments on small fragments of feldspar the size of a poppy seed, it makes effective the old known methods, especially those for determination of the melting point, and of the flame reaction for sodium and potassium. For the experiment by the gas flame it requires many appliances and considerable practice. According to Szabo's report, his five stages of the sodium flame show: 0.3–1 per cent, 1–2 per cent, 2-4 per cent, 4–8 per cent, 8-16 per cent of sodium, and the four stages of the potassium flame: 0.3–1 per cent, 1–4 per cent, 4–13 per cent, and 13–22 per cent of potassium.

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[1] Journ. f. prakt. Chemie XCV, (43) and XCVIII, (14).

[2] Volcanic rock of Fichtelgebirges, München, 1874.

[3] Nouveaux procédés d'analyse médiate des roches, etc. Comptes rendus 1874, XXII, (11).

[4] N. Jahrb. f. Min. etc., 1875, (74).

[5] Tschermak's Min. Mitth. 1876.

[6] Budapest, 1876. From the Hungarian original, published by the Hungarian Academy, d. w. 1873.

Though I gladly availed myself of the chance of reading Szabo's book, when its title page met my eye, yet, after a painstaking study of it I was obliged to lay it aside unused. because my small private laboratory does not support the luxury of gas-lighting, and at the University in this place neither a laboratory nor any such means of help is at my disposal. Nevertheless, I found myself compelled to seek another way to the same end, *i. e.*, the determination of the feldspars, and the ability in my future work to eliminate the expression, so much cherished in modern petrology, "plagioclase," by means of the accurate designation of the feldspar group.

I first turned my attention to the pure feldspar, but after a series of experiments which I began in August of last year, I extended my work to all minerals which contained alkalies or alkaline earths, and became convinced that my method could be applied not only to the determination of the most minute mineral fragments, but also under the same circumstances, to the determination of minerals in thin sections of cryptocrystalline rocks.

When I had become convinced that in the most common operations in analytical chemistry, for example, the formation of successive precipitates, filtering, decanting, etc., not much is to be accomplished in the substantial investigation of minerals in thin sections, it occurred to me to cause special gaseous material (as hydrofluoric gas, chlorine gas) and such liquid substances as continually volatilize (as hydrofluosilicic acid), to act upon thin sections of minerals, and to utilize the substantial changes which present themselves upon the upper surfaces of thin sections and admit of a microscopic investigation, to the determination of minerals.

First of all I thought of the etchings of crystallographically determined mineral sections, then upon the successive removing and separate investigation of individual new-formed products, through various solvents and reagents; but the observation of beautiful, characteristic crystals which appear on some specimens, soon taught me that a far more important role is to be attributed to the new products formed from the investigated minerals—so far as they can be obtained in easily recognized crystal forms and as far as the individual chemical mineral elements, especially those of the alkalies and alkaline earths, can be investigated by these crystals and determined according to their quantitative relation—since by this means, results are to be obtained in the shortest and most convenient way (for those who are not expert in chemical operations), while for the same results analytical chemistry requires much time and experience.

The first substance which I used was hydrofluoric gas. I was convinced that by its action upon alkaline silicates, silicicfluorides of the alkalies would be formed, which, dissolved in boiling water, can by the evaporation of the solution be obtained in the characteristic crystals, differing for potassium and sodium. I thus saw the possibility realized of being able to separate with great readiness and in the smallest specimens all silicates containing potassium from those containing sodium, especially potassium feldspars from the soda and lime feldspars, and in general alkaline from non-alkaline silicates. Besides this there appeared some accompanying phenomena which seemed to me to be important as means of recognizing the minerals. Thus, for example, I saw that besides the alkaline silicates a long series of non-alkaline silicates is affected by hydrofluoric gas, and that all those minerals from which fluorides are formed can be easily recognized by effervescence in sulphuric acid (which can be easily observed in the microscope); I saw that in the sections of phonolite treated with HF and then boiled in water, Möhl's nepheline-glass was reduced to rather sharp edged sections of nepheline, that through similar treatment wholly turbid as well as very thin sections of porphyry became perfectly clear and bright, and thus their mineral composition and that of similar minerals could be easily recognized.

But the original problem of this work, the determination of those groups of the feldspar family which we unite under the names of oligoclase, andesine, labradorite and anorthite, could not for a long time be solved in a simple way. After I had established the fact through experiments that from the soda-lime feldspar treated with HF, all the alkalies are dissolved as silicicfluorides, by boiling away in water, while the greater part of the calcium remains behind in the specimen either as a fluoride or as an aluminous lime fluoride,[1] I struck upon several ways of reaching the desired end, that is, for determining approximately the quantitative proportions of calcium and sodium in the feldspars, which ways proved more or less successful, but none of which satisfied me on account of their minuteness.[1]

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[1] If the silicicfluoride of calcium had been formed, it would as one of the most readily soluble silicicfluorides, have been quickly and perfectly dissolved in the water.

Naturally it occurred to me to produce in the form of silicicfluorides the sodium as well as the calcium of the lime-soda feldspars, since the artificial salts of both elements showed various, easily distinguished crystal forms; then my attempt went so far as to change calcium fluoride into silicicfluoride. For this end I treated the specimens changed by HF with hydrofluosilicic acid, but I found to my sorrow that the silicicfluoride crystals from sodium were always to be found in a considerably larger quantity than the proportion for the calcareous feldspars demanded. And for this reason I suspected that in the indicated proportions a considerable portion of the silicicfluoride of calcium crystallizes in the same form as the silicicfluoride of sodium.[2]

Since I intended to seek for the reason of the similar crystallization of substances appearing elsewhere in various forms, in the similar conditions of solution under the circumstances named, I simplified the investigation by treating the specimen directly with hydrofluosilicic acid in order to bring the very soluble silicicfluoride of calcium to formation and solution more quickly than the less soluble silicicfluoride of sodium. And these experiments had the desired result in that they demonstrated a decided difference in the silicicfluoride forms of potassium, sodium, calcium (eventually strontium), magnesium (eventually iron, manganese), occasionally also of lithium and barium, as well as made possible a quite easy separation of them. Besides this, my efforts went so far as to make known the reactions for the silicicfluorides similar in their forms to the individual elements named, in order to acquire complete knowledge of their substantial differences even in doubtful cases.

The use of chlorine gas as a reagent offered many advantages, thus: For the proof of insolubility in acids, for the proof of alkalies, for producing the characteristic etchings (in some minerals), especially, however, for establishing whether the silica which separates out of the thin section of a silicate is gelatinous or granular. And of the older methods that of heating the specimen showed itself in most cases applicable to the recognition of the coloring metals, and to the approximate determination of the melting point, and that of the clay reaction by means of cobalt solution with microscopic investigation, to the thin sections of different kinds of rocks.[1]

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[1] I reported these methods in the session of the mathematical and physical science classe d. k. böhm. Gesells. d. w., on Nov. 10, 1876.

[2] From treatment with sulphuric acid were formed many of those broad monoclinic crystal needles, formerly only the peculiar silicicfluoride forms of sodium, which I took for the formtypes of gypsum crystals.

Since I already use the methods explained here, though probably capable of further development, in those studies whose publication is reserved to the archives of the general scientific investigations of Bohemia, I consider this little book as an introduction to my further petrological work, and herewith venture to justify its insertion in the archives of general scientific investigation.

In conclusion the pleasant duty remains to me to express my warmest thanks to my highly esteemed colleague, Prof. Stolba, for furnishing me with a quantity of chemically pure silicic acid which was necessary for my experiments, and for his advice concerning the latter.

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[1] Upon all these methods I have already made communications in the session d. k böhm. Gesells. d. w. on Feb. 9 of this year.

## I. GENERAL METHOD FOR THE MICRO-CHEMICAL DETERMINATION OF THE METALS OF PETROLOGICALLY IMPORTANT MINERALS BY MEANS OF HYDROFLUOSILICIC ACID.

### *Principle of the Method.*

With the exception of a few which offer the greatest resistance to chemical reagents, all minerals which contain alkalies, alkaline earths, heavy metallic monoxides (or analogous sulphur, selenium, tellurium, arsenic, or antimony compounds) are more or less affected by strong hydrofluosilicic acid.

The result of this action is the formation of silicicfluorides (from the metalic elements of the minerals and the hydrofluo silicic acid), which dissolve in the hydrofluosilicic acid solution and after the evaporation of the solution make their appearance in beautifully formed crystals (or of small groups of them) characteristic of the individual elements.

If the treatment of a very small piece of mineral with hydrofluosilicic acid is performed upon a spot on the object glass coated with thoroughly boiled Canada balsam, the silicicfluorides thus formed can, even in their minuteness, be studied, magnified to any desired degree.

If the silicicfluorides of the individual metals, which are formed upon the object-glass under the conditions mentioned could be separated from each other, either through the different crystal systems to which they belong, or through definite, easily recognized typical forms, or through characteristic changes when treated with new reagents, perfectly reliable means for distinguishing the individual metals would thus be afforded.

Of the silicicfluorides, thus far known, of the metals appearing in petrologically important minerals, those of potassium, cæsium, and rubidium belong to the tesseral crystal system, and those of sodium, magnesium and iron to the hexagonal or hemihedral-hexagonal system, while those of lithium, calcium and strontium (according to Marignac's statement) must be monoclinic.

In the determination of a petrologically important mineral it is hardly of importance to prove the presence of cæsium and rubidium with potassium.

The silicicfluorides of sodium, magnesium and calcium produced under the conditions mentioned show such different forms that they can, in most cases, be distinguished at the first glance. Moreover the silicicfluolithium crystals, produced from lithia-mica and lithia-iron-mica are so peculiar as to be quite easily identified; but silicicfluostrontium presents almost the same crystal appearance as silicicfluocalcium, and in nearly the same forms in which silicicfluomagensium appears; we find also silicicfluorides of iron and manganese; so that a separation of the silicicfluoride of calcium from that of strontium and of magnesium from those of iron and manganese would scarcely prove successful.

But the separation of the last named metals in the forms of silicicfluorides is not rendered impossible on this account; for by treating them with new reagents the desired end is quite easily reached.

If, for example, silicicfluocalcium and silicicfluostrontium are treated with dilute sulphuric acid, the crystals of the first are, after a few seconds, surrounded by a thick beard of monoclinic gypsum needles, while the crystals of silicicfluostrontium very slowly (in several hours) liquify into a granulous mass, or only very short (celestine?) needles, are here and there observed. In the same way can the silicicfluorides of magnesium, iron and manganese be separated by the application of various substances. The application of chlorine gas is worthy of recommendation, by means of which the silicicfluoride of iron assumes an intense citron-yellow color, while silicicfluomagnesium and silicicfluomanganese remain almost colorless: yet the manganese salt has a streak of red, and appears strongly agglutinated, and for the most part changed into a group of little tablets, prisms and melted grains, although the crystal forms of silicicfluoride of magnesium appear to be changed a little.

Also the application of sulphide of ammonium vapor for the separation of the last-named metals in the form of silicicfluorides produces exactly the same results.

From these experiments it can be seen that the metals appearing in petrologically important minerals in the presence of hydrofluosilicic acid may be easily identified. At the same time, moreover, the quantitative proportions of the several metals existing in a mineral can in most cases be approximately ascertained.

If the mineral is readily acted upon by the hydrofluosilicic acid all the metals in their variously formed silicicfluorides make their appearance after the evaporation of the solution, and, indeed, (if they do not materially differ in their conditions of solubility) in about the same quantitative proportions in which they existed in the mineral investigated. If, however, the mineral to be analyzed is only slightly attacked by the hydrofluosilicic acid, the latter has acted on the greater part or the whole of that metal (of the respective metals) which can be most easily dissolved, while for the other metals of the same mineral only small silicicfluoride crystals or none at all are observed.

The conditions of the silicicfluorides in solution must, consequently, be considered, as well as the comparison of the quantitative proportions of the silicicfluorides, with the quantitative proportions of the metals contained in the original minerals.

If from several metals which the mineral under investigation contains, at the first treatment with hydrofluosilicic acid only one makes its appearance, then the treatment of the same portion of mineral is to be repeated with fresh hydrofluosilicic acid, which treatment usually produces the wished for result; that is the making visible of the remaining metals in the form of silicicfluorides. It is evident, however, that in this fortunately rare case the quantitative proportions of the silicicfluorides will not correspond with the proportions of the metals which the chemical analysis of the mineral demands, but that, for approximate determination of the quantitative relations of individual metals in the mineral to be examined, other methods, to be explained later, must be employed or special experiments (with hydrofluosilicic acid) must be established as rules for these individual minerals,

It may be remarked here that thin sections are more readily acted upon than cleavage particles or broken fragments.

In conclusion I think I may say that clay, and sesquioxides in general, and minerals which are free from monoxides, afford when treated with hydrofluosilicic acid, no new formed products in crystal forms.

### EXECUTION OF THE METHOD.

Place a few drops of Canada balsam upon an object-glass and hold it over a spirit lamp until the little bubbles which form have passed off, and the balsam acquires, after cooling, a firm, resinous consistency. At the same time try so to turn the object glass while the balsam is still liquid, that it will form in hardening as thin and even a coating as possible upon the glass.

In the middle of the balsam layer place the specimen or thin section of the mineral to be examined, and again heat the object-glass, but only enough to cause the specimen to adhere firmly. If the specimen is a thin section, let it be as thin as possible, because it loses something of its transparency by reason of the crust of silicicfluoride; then it must be heated cautiously (to prevent the formation of little vesicles), and carefully pressed with a penknife so that no little gas bubbles remain under it and that it may assume a perfectly horizontal position,

The size of the specimen is entirely arbitrary. It may be the size of a pea, or it may be a very much smaller piece; yet it is advisable to keep a certain relation to the size of the drop of hydrofluosilicic acid which is to be put upon it.

I usually take a specimen of mineral about the size of a pinhead or a millet grain, and place upon it a drop of hydrofluosilicic acid of about the size of a pea, If two or more pieces of minerals are taken of the above mentioned size, the drops of acid must be increased in a proportionate degree. I take a thin section of the size of 4-6$^{mm}$, taking care that the hydrofluosilicic acid placed upon it does not spread over the section, but that the drop maintains the greatest height possible, so that the greatest depth of fluid may work upon the smallest surface.

If one has to investigate a mineral dissolved in water it is advisable to take a larger amount than the above mentioned relation to the quantity of acid required, because, besides the silicicfluoride of the metal which is contained in the specimen, the crystal form of the specimen itself (either of the unchanged mineral or of its individual salts) is also brought to perfection, and one has a complete analysis of the mineral before his eyes. For example, if the specimen were a sodium salt, such as sodium-chloride, sodium-nitrate, mirabilite or borax, from each substance would be obtained short hexagonal prisms of silicicfluoride of sodium, but besides this in the first specimen little cubes of sodium-chloride, in the second rhombohedrons of sodium nitrate, in the third monoclinic needles of glauber salt. and in the fourth borax crystals easily recognized by their form: but from polyhalite one would find near the fluorides of the individual metals little crystals of gypsum, etc.

The hydrofluosilicic acid applied must be perfectly pure so that no silicicfluoride crystals be left upon the balsam plate of the object-glass when dried. The hydrofluosilicic acid prepared according to the direction of the analyst[1] is useless for our purpose for the reason that it is prepared and preserved in glass vessels so that it already contains various silicicfluorides. (whose metals come from the glass).

The hydrofluosilicic acid which I used was prepared by my assistant, Mr. Plaminek, by the introduction of fluosilica, obtained from fluoride of barium, sulphuric acid and pure quartz powder in a lead retort, into a platinum crucible filled with water, and this after moderate dilution was decanted in a caoutchouc flask for preservation. For transferring the drop of hydrofluosilicic acid upon the specimen (situated upon the balsam surface of the object-glass) I use a caoutchouc stick. which has a spoon-shaped rim upon the end, which may be used in dipping.

In regard to the strength of the hydrofluosilicic[2] acid, the following should be taken into consideration: If the acid is too weak most minerals are not acted upon at all, or only slightly; if it is too strong, then so many silicicfluorides will be formed. and, in addition, from the silicates so much silicious earth will be separated, that the field of vision becomes entirely dark or opaque, and no crystal forms can be distinguished—thus it is, for example, with a thin section of elæolite. In such a case the difficulty is easily remedied if one or two drops of water are added to a drop of hydrofluosilicic acid of the same size as before, for a new trial.

According to Mr. Plaminek's statement my hydrofluosilicic acid is about 3½ per ct. strong. And this attacks thin sections of albite, orthoclase, muscovite, tourmaline, and pleonaste, and causes the formation of silicicfluorides.

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[1] Anleitung zur qual. chem. Analyse. Fresenius, 1866, page 51. Und Stolba. Ueber die Bereitung der kiesel flussaure im Kleinen. Dingler's polytechn. Jour. B. CXCVII, page 336 (1870).

[2] Stolba (J. f. prakt. Chemie XC, 193) has designed, upon the basis of two series of experiments, a table upon the specific gravity of dilute hydrofluosilicic acid of different values (to 34 per ct.). He finds that the specific gravity increases regularly for every half per ct. Thus at 17.5°, for hydrofluosilicic acid of

|  | 0.5 per ct. | 1 per ct. | 1.5 per ct. | 2 per ct. | 5 per ct. | 10 per ct. |
|---|---|---|---|---|---|---|
| the specific gravity is | 1.004 | 1.008 | 1.012 | 1.016 | 1.0407 | 1.0834 |

When the specimen has been treated with hydrofluosilicic acid, bring the object-glass (holding it always in a horizontal position) to a level place quite free from dust, and cover it with a tumbler or inverted glass under which has been placed a little cup of sulphuric acid. I place the object-glass with the specimen and acid upon the perfectly even and horizontal surface of a rather large mahogany chest, but must wait twenty-four hours for the complete drying of the drops, although in perfectly dry air only a few hours would be required.

A brief resumé of the detail of the operation may be given in the following words: The specimen placed upon an object-glass previously coated with a layer of balsam, is covered with one or two drops of hydrofluosilicic acid and allowed to lie intact and in perfect rest in a horizontal position and protected from dust until the drying of the drop is accomplished. And this entire preparatory work requires hardly five minutes time.

When the drop of hydrofluosilicic is dried the preparation is ready for microscopic examination.

## MICROSCOPIC CHARACTERS FOR THE DETERMINATION OF THE SILICICFLUORIDE FORMS OF THE METALS APPEARING IN PETROLOGICALLY IMPORTANT MINERALS.

(*Developed by hydrofluosilicic acid.*)

The metals appearing in minerals of petrological importance are potassium, (cæsium, rubidium), sodium, lithium, calcium, strontium, barium, magnesium, iron and manganese.

The silicicfluoride of potassium ($K_2SiF_6$) (Plate I, Fig. 1, a, i) prepared from orthoclase, microcline (Plate I, Fig. 2 and Fig. 16), leucite (Plate II, Fig. 2), muscovite (Plate II, Fig. 5, at the right), biotite (Plate I, Fig. 1, e, m, n, r)* and some other minerals,[1] magnified to four hundred times the original size, appeared always in sharp-edged crystals with smooth surfaces and usually small. These crystals belonged to the tesseral system and always remained dark between the crossed herapatites.

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[1] Saltpeter, sylvine, potassium-alum.

*In this translation the English letters are substituted for the Greek, viz.: *a* for alpha, *e* for epsilon, *i* for iota, *s* for sigma, *n* for nu, *m* for mu, *r* for rho, etc.

The most common form was the hexahedron whose little crystals were occasionally united[1] in pretty chandelier-like groups; quite frequently the combination forms $\infty 0 \infty .0$; or $\infty 0. \infty 0 \infty$ made their appearance, the latter especially when the specimen had been treated first with fluohydric gas and then with hydrofluosilicic acid.

Upon the imperfect development of the larger crystal forms the surfaces appeared in the form of steps or displayed a beautiful structure of scales.

According to Marignac[2] and Stolba[3] the silicicfluoride of potassium crystallizes in octohedrons (probably from the pure water solution).

According to Stolba's statement one part of silicic fluoride of potassium requires 833.1 parts of water at a temperature of 17.5° and 104.8 parts of boiling water.

In hydrochloric acid this silicicfluoride is the more soluble the stronger the acid is: for according to Stolba's experiments[4] HCL of the strength of 26.5, 14.1, 9.6, 2.7, 1.8 per cent. dissolves of silicicfluoride of K 237, 340, 357, 376, 409 parts, at the temperature of 14 degrees.

At 17.5 degrees the specific gravity of this fluoride is 2.6655 —2.6649.[5]

The silicicfluoride of sodium ($Na_2SiF_6$) (Plate I, Fig. 4), prepared from albite (Plate II, Fig. 1), pericline, the oligoclase feldspars (Plate I, Figs. 17-19), nepheline (Plate II, Fig. 3), scapolite (Plate II, Fig. 4), and several other minerals,[6] appeared always in short hexagonal prisms which were either terminated by basal planes or more frequently by a blunt pyramid, and whose vertical edges were often truncated by secondary pyramids, ($\infty$P2). Imperfectly formed crystals of silicicfluoride of sodium had barrel-shaped, oval or cylindrical forms.

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[1] Beautiful groups of this kind were obtained from the aqueous solution of feldspathic mixed portions of syenite from Plauenschen Grunde, near Dresden, and of amazonite from Miask, when treated with fluohydric gas. (Plate I, Fig. 2.)

[2] Comptes rendus, xlv, 650.

[3] Jour f. prakt Chemie. xc. 193.

[4] Jour. f. prakt. Chemie, ciii, 396.

[5] The silicicfluoride of cæsium ($Cs_2SiF_6$) crystallizes from a dilute solution (through voluntary evaporation) into cubes with truncated corners. At 17 degrees it dissolves in 166 parts of water and more easily in hot water. In alcohol it is insoluble. (*C. Preis. Jour. f. prakt. Chemie.*, ciii, 410.)

The silicicfluoride of rubidium ($Rb_2SiF_6$) crystallizes in the combination forms $\infty 0 \infty .0. \infty 0$, dissolves at 20 degrees in 614 parts of water, and at 100 degrees in 78.8 parts water. In acids it is easily soluble. In spirits of wine insoluble. Its specific gravity at 20 degrees is 3.3383 (*Stolba. Jour. f. prakt. Chemie.* cii. 1).

The silicicfluoride of thallium, prepared by treating the carbonate of thallium monoxide with hydrofluosilicic acid and evaporating the solution, crystallizes in tesseral, six sided tablets, or distorted octohedrons which are easily soluble in water. (*Gmelin's Handb. d. anorgan. Chemie.*, 1875, *Bd.* 3, *p* 193).

[6] Rock-salt, sodium nitrate, borax, cryolite, phosphorus-salt.

Between the crossed Nicols appeared all the forms of silicicfluoride of sodium colored yellow or blue; they were all dark except those arranged at right angles with the main axis.

Marignac (Jahresb. über Fortschritte der chemie,) etc., v. Kopp u. Will, 1858, [für 1857], p. 129,) takes the crystals of silicicfluoride of sodium for holohedral forms ($\infty$P.0P. P. $\infty$P2) and adds $\infty$P: P = 123 deg. 3 min.

According to Stolba (Jahresb. über Fortsch. d. Chem. etc., 1858 [für 1857] p. 129) one part of the silicicfluoride of sodium requires for its solution 153.3 parts of water at a temperature of 17.5 deg. and 40.66 parts of boiling water; it easily forming an oversaturated solution.

Its specific gravity is 2.7547.

The presence of a larger quantity of silicicfluoride of calcium has a noticeable influence upon the length of the hexagonal prisms of silicicfluoride of sodium. I have prepared three specimens differing in the quantity of both silicicfluorides. In the first specimen were two parts by weight of the sodium-salt, with one part, by weight, of the calcium-salt; in the second specimen equal parts, by weight, of both silicicfluorides, and in the third specimen one part, by weight, of silicicfluoride of sodium and two parts, by weight, of silicicfluoride of calcium The crystals of silicicfluoride of sodium in the second specimen were one-half longer than those in the first, and those in the third were double the length of those in the first. (Plate I, figure 7 and figure 8.)

The silicicfluoride of lithium prepared from the rose-red lithia-mica from Roznau in Moravia, and from a light lithia-iron mica from Zinnwald (Plate II, fig. 5, at the left) appeared, when magnified to 400 times, in minute, sharp-edged, six sided pyramids, which usually presented the appearance of a regular blunt, hexagonal pyramid. At times, however, a couple of surfaces were developed to such an extent, that the other surfaces of the distorted rhombic or rhomboidal forms could hardly be distinguished.

The silicicfluoride of lithium (Plate I, fig. 3) represented from the preparation of Prof. Stolba by recrystallization presented circular forms, notched or undulating at the edge, fibrous, striated within or ornamented by several concentric circles.

Occasionally. by the overlying of imperfectly formed crystal-prisms, these forms appeared to resemble cauliflower buds or blossoms and among them were found many little tablets with a regular six or eight sided appearance, sometimes also, ornamented with concentric inner circles, which remained dark between crossed Nicols. If one should consider the latter hemihedral forms of the hexagonal system, they would be regarded as combination forms of 0R.—R.∞R. and 0R. R.—R.∞R.∞P2. Besides these there were found in the preparation a few very short, hexagonal prisms.

According to Marignac (Ann. Minn. [5], XV, 221)[1] the silicicfluoride of lithium ($Li_2$ $SiF_6$ $+2H_2O$) is monoclinic and appears in the form of combination ∞P.0P.Ᵽ∞.⅓Ᵽ∞.—Ᵽ∞. In the clinodiagonal chief section is ∞P:∞P=83° 38′, 0P:∞P=108° 14′, 0P: Ᵽ∞=96° 36′, 0P:—Ᵽ∞=139° 42′. The crystals are quite easily cleavable parallel Ᵽ∞, less easily parallel 0P. They decompose in the air.

According to Stolba the silicicfluoride of lithium may be obtained by evaporating a solution of carbonate of lithium in a slight excess of hydrofluosilicic acid. The salt crystallizes, after voluntary vaporization, in transparent, four-sided, obliquely truncated prisms or irregular six-sided tablets which dissolve at a moderate temperature in 1.9 parts of water, also in alcohol but are insoluble in ether or benzol. Their specific gravity is 2.33.

The silicicfluoride of calcium (Plate I, Fig. 6), prepared from oligoclase feldspar (Plate I, Figs. 17–19), anorthite (Plate I, Fig. 20), wollastonite, amphibole (Plate II, Fig. 7), diallage (Plate II, Fig. 8), scapolite (Plate II, Fig. 4), epidote and other minerals[2], forms peculiar, long, pointed, thornlike crystals, branching and usually spindle-shaped; sometimes, also, in the form of rhomboidal tablets which are often united in star-like or other groups, and in most cases are recognized at the first glance. Many of the spindle-shaped forms are bounded by six lateral planes and terminated by one basal plane so that they appear like very sharp rhombohedrons truncated by basal surfaces. At times they appear very abundant in six-sided forms which resemble pointed rhombohedrons (about—2R of calcite).

A characteristic feature of these crystal forms (of silicicfluoride of calcium) produced by hydrofluosilicic acid from thin sections or fragments of mineral is the lack of sharp rectangular edges and smooth surfaces and the presence very often of a peculiar grayish or brownish dusty character, probably because of the inclusion of delicate bubbles.

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[1] Und Jahresber ü. d. Fortschr. d. Chem. 1860 (pro 1859) 107.

[2] Calcite, dolomites, polyhalite, anhydrite, gypsum, fluorite-albite, titanite, scheelite.

The silicicfluoride of calcium prepared by Prof. Stolba, forms mostly four-sided, rarely six-sided prisms (Plate I, Fig. 5) and needles which are terminated by an oblique terminal plane or by one prominent and several small oblique planes. These crystal needles are often united in radiated, spherical groups resembling warts.

According to Marignac (Comptes rendus XLVI—854 und Jour f. prakt. Chem, LXXIV—161) the silicicfluoride of calcium ($Ca\ Si\ F_6 + 2\ H_2\ O$) crystallizes in monoclinic, microscopic crystals which are probably isomorphous with silicicfluoride of strontium.

According to the report of my colleague Herr Stolba, and my own experiments, the silicicfluoride of calcium is readily soluble in water.

The silicicfluoride of strontium prepared from strontianite by means of hydrofluosilicic acid, and from the preparation of Herr Stolba by recrystallization, (Plate I. Fig. 9) appears in sharp-edged, smooth-surfaced prisms and needles which can scarcely be distinguished from the crystal forms of silicicfluoride of calcium produced from the preparation of Herr Stolba, except that they occasionally exhibit a greater abundance of planes.

According to Marignac (Jahresb. über Fortschr. d. Chem. von Kopp and Will 1859 [für 1858] pag. 145 u. 1860 [für 1859] pag. 107) the silicicfluoride of strontium ($Sr\ Si\ F_6 + 2\ H_2\ O$) is monoclinic. In the clinodiagonal principal section are $\infty P : \infty P = 84° 16'$ and $0P : \infty P = 103° 13'$.

The silicicfluoride of barium prepared from calciferous witherite (in the form of a microscopic preparation) by means of hydrofluosilicic acid, presents, when magnified four hundred times, extremely slender sharp-pointed needles, whose form although sharp-edged and smooth-surfaced is very hard to determine on account of the minuteness of the crystals.

According to Stolba (Jour f. prakt. Chemie XCVI. 22) the silicicfluoride of barium presents microscopic elliptical, cruciform, divergent and roundish groups. Prepared from a dilute solution slowly evaporated it appears in slender needles.

One part of silicicfluoride of barium requires for solution, according to Stolba, 3731 parts of water at a temperature of

17.5°, 3313 parts at a temperature of 21° and 1175 parts of boiling water. It is easily soluble in acids and in salts—namely, in 448 parts 4½ per cent muriatic acid and in 272 parts 8 per cent nitric acid. Its specific gravity at 21° Temp. = 4.2741.

The silicic fluoride of magnesium prepared from humite, chondrodite (Plate I, Fig. 10), talc, biotite (Plate II, Fig. 6), rubellan, hypersthene, bronzite (Plate II, Fig. 9), and several other minerals,[1] appears in rhombohedrons whose vertical angles are usually truncated through the basal surface, or in combinations of R. ∞P2, R. ∞P2. 0R and other rather complicated rhombohedral forms.

All its crystal forms have sharp edges and smooth faces.

Upon two little crystals (of the microscopic preparation) having the combination R. 0R, which were found in an almost vertical position and remained dark between the crossed herapatites, I was able to measure the angles of horizontal projection. I found angles from 119° to 121°, therefore about 120°. In other positions between the crossed herapatites the crystals appeared colored red, yellow and blue.

Quite often the silicicfluoride of magnesium appears in rhombohedrons distorted on one edge, also in conical, cruciform, feathery and other imitative forms which sometimes have in the entire preparation the same regular arrangement, and every projection of which tends to terminate in an imperfectly formed rhombohedron.

The silicicfluoride of magnesium is quite easily soluble in water.

The silicicfluoride of iron ($FeSiF_6$ [$+6H_2O$?]) prepared by dissolving iron in hydrofluosilicic acid and evaporating the solution (in an iron crucible) in the air, usually crystallizes in pale bluish-green regular six-sided prisms (∞P2) which terminate in a rhombohedron.[2] Prepared in the form of a microscopic preparation (Plate I, Fig. 15) from the salt obtained from Herr Stolba and from siderite, it shows many individual and combined forms, also distorted forms of the hemihedral hexagonal system which appear colorless and can hardly be distinguished from the crystals and imitative forms of the silicic fluoride of magnesium.

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1. Bastite, pennite (Plate I, Fig. 11), cordierite (Plate II, Fig. 10), olivine (Plate II, Fig. 11 and Fig. 12), brucite, mesitine, magnesite (Plate I, Fig. 12).

2. *Berzelius. Gmelin's handbook of inorganic chem*, 1875, *B*. 3, *p*. 403. On the appearance of the silicicfluoride of iron, see *Stolba. Sitzb. d. math. naturw. Cl. d. k. böhm. Ges. d. w. v.* 27 *oktbr*. 1876.

It is easily soluble in water.[1]

The silicicfluoride of manganese ($MnSiF_6+6H_2O$) appears according to Marignac (*Ann. Chem. ph.* [3], LX, 301, *u. Jahresber. ü. Fortschr. d. Chemie* 1861 [*pro.* 1860] *p.* 98) in pale reddish white crystals of the hemihedral hexagonal system, in the combination form ∞P2.R. According to the same investigator R : R=128° 20′.

Prepared in the form of a microscopic preparation (from the salt obtained from Herr Stolba and from dialogite, through the treatment of the latter with hydrofluosilicic acid) it appears in the same forms as the silicicfluoride of iron and the silicicfluoride of magnesium so that a separation of the three silicicfluorides according to type forms would hardly be successful.

*Separation of the Silicicfluoride forms of Calcium and Strontium by means of Sulphuric acid* (*and more particularly as a test for the presence of Calcium*).

If these silicicfluorides are treated with concentrated chemically pure sulphuric acid which has been diluted with an equal volume of water the crystals of the silicicfluoride of calcium are, after a few seconds, surrounded by a thick beard of colorless monoclinic needles, (gypsum crystals), while upon the crystals of strontium only a very slow solution into little grains (among which, a very few, extremely small, short needles [celestine?] are seen in some places) is to be noticed.

After some hours the preparation containing the silicicfluoride of calcium presents an aggregated mass of striated, very long, monoclinic needles and prisms, while in the preparation containing silicicfluoride of strontium nothing new is to be noticed except a few shapeless crystals.

I perform this experiment in the following way: Upon a watch crystal by means of a very finely drawn out tube, I place a few drops of concentrated chemically pure sulphuric acid; upon a second watch glass an equal number of drops of water of the same size as the drops of acid. Now I put a few drops of the mixture of the two substances upon the silicicfluoride, formed from the specimen, and place the cover-glass upon it and bring the preparation upon the table of the microscope. At this point one must move it very carefully, that the table of the microscope may not be soiled. Later on it will be noticed that the balsam plate is colored red (blood red) by the sulphuric acid; but since it does not lose its transparency this is no hindrance to the success of the experiment.

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[1] Silicicfluoride of iron ($Fe_2Si_3F_{18}$) prepared by dissolving ferric hydrate in hydrofluosilicic acid and evaporating the solution, forms a yellowish jelly and after complete drying a half-transparent blood-red gumlike mass, which dissolves easily in water. (*Gmelin's Handb. d. anorg. Ch.*, 1875, *p.* 403.)

It might be noticed here that hexagonal prisms of pure silicicfluoride of sodium had, after one and one-half hours in sulphuric acid diluted with an equal volume of water, undergone no change except that they had assumed a slight reddish color. If on the contrary—prepared openly under other conditions which will be explained hereafter—they contained calcium, they dissolved, the more rapidly the more calcium they contained. Monoclinic gypsum needles shot up and increased quite rapidly upon the sides of the hexagonal prisms. The silicicfluoride of calcium, now changed into a sulphuric acid solution, separated again gradually into short hexagonal prisms, whose mass was greatest about the third day after the experiment; but about the fifth day after the experiment these crystals of silicicfluoride of sodium formed by crystallization in the sulphuric acid (diluted with an equal volume of water) had entirely vanished.

### *Separation of the Silicicfluorides of Magnesium, Iron and Manganese.*

*a.* By the action of chlorine gas.

Place the object-glass upon which are the silicicfluorides of magnesium, iron and manganese, on a low frame (for example upon an inverted porcelain crucible) contained in the chlorine gas apparatus (which will be represented and described later) and heat the apparatus gradually so that small but numerous bubbles may be developed from the manganese muriatic acid solution. After the development of gas has continued from one and one-half to two minutes, the preliminary experiment may be considered complete.

Take out the object-glass, dry it carefully and place it upon the table of the microscope. In order, however, to protect the object-glass in all possible cases against accident, the silicicfluoride treated with chlorine gas may be furnished with a cover glass.

Upon observing all these silicicfluorides under the microscope, one finds that the silicicfluoride of iron has taken an intense citron-yellow color, without having lost much of the sharpness of its crystal forms. The silicicfluorides of magnesium and manganese on the other hand, have remained almost colorless. The first shows a streak of grey, the second of red, and while the silicicfluoride of manganese has suffered a transformation into little crystals, melted prisms, tablets and grains, or seems entirely dissolved, the crystals of silicicfluoride of magnesium have only melted a little at the corners, so that they remain almost unchanged.

*b*. By means of ammonium-sulphide gas.

In a beaker place an inverted porcelain crucible, upon which lay the object-glass on which are the three silicicfluorides. Pour into the beaker a little pure sulphide of ammonium and cover with a glass plate; or yet simpler, hold the silicicfluorides over the opening of a flask filled with pure sulphide of ammonium.

In both experiments it will be noticed that the silicicfluoride of iron changes quite rapidly to blackish-gray with a peculiar metallic bronze lustre; while the silicicfluoride of manganese appears reddish or brownish-white and the silicicfluoride of magnesium grayish-white. Under the microscope the crystals of silicicfluoride of iron are quite black, in the thinnest places blackish-yellow; those of magnesium grayish-white, and those of manganse a peculiar reddish-gray, the last being sometimes changed into a granular mass. Near the forms of the two last named silicicfluorides, newly formed crystals of silicicfluoride of ammonium were noticed.

*Completion of the preparation for the purpose of its preservation.*

If it is desirable to preserve the preparation carrying the crystallized silicicfluorides as a proof of the result of the experiment, a cover glass must be fastened upon it.

If the investigated object is a thin section whose surface acted upon by hydrofluosilicic acid show distinct etchings it is better to cover it not with Canada balsam but with a thin layer of air, which can be managed by laying the cover glass directly upon it and cementing in at the margins with Canada balsam, made viscous by previous warming.

If the specimen is a thin section, upon which no peculiar etchings are observable, it can be covered with Canada balsam in the usual way and furnished with a cover glass. Yet the following method is advisable: lest the silicicfluoride crystals may be misplaced by the application of the Canada balsam and the pressure of the cover-glass, viz: use a rather weak solution of balsam—as one part Canada balsam and two parts chloroform

—lay the cover-glass carefully upon it and press it slowly and softly.

If the object is a grain of mineral, which was not wholly dissolved in the drop of hydrofluosilicic acid, remove the remnant with clean pincers if it would prevent by its projection the application of the cover-glass, and complete the preparation in the usual manner.

### *Remarks upon the Investigation of some of the petrologically important mineral groups according to the foregoing method.*

*a.* Investigation of the Feldspar group.

Among the branches of the feldspar group, orthoclase (sanidine), microcline and albite (pericline), in the form of cleavage sections, are least affected by hydrofluosilicic acid; they, therefore, usually require a repeated treatment with this acid, or better still a treatment with fluohydric gas, which will be discussed later.

But if these same minerals in the form of thin sections are treated with strong hydrofluosilicic acid, the first attempt to gain knowledge of their chemical nature is apt to be sufficient. Orthoclase and microcline (Plate I, Fig. 16) which can easily be distinguished from each other by their internal structure, offer, on treatment with hydrofluosilicic acid tesseral crystals ( $\infty 0 \infty$ . 0, $\infty 0$. $\infty 0 \infty$ ) of silicicfluoride of potassium, and near them are often found very many tiny hexagonal prisms and tablets of silicicfluoride of sodium. Albite and pericline furnish only silicicfluoride of sodium (observed when magnified to the 400th power). Oligoclase poor in calcium, treated with hydrofluosilicic acid, gives (magnified to the 400th power) the same crystals as albite and pericline, extremely small but usually numerous hexagonal tablets (and very short prisms), which sometimes crowded closely together resemble very tiny spherical forms; but near them scattered individual spindle-shaped or other crystals of silicicfluoride of calcium are usually noticed.

Oligoclase rich in calcium furnishes with similar treatment distinct hexagonal prisms and numerous spindle-shaped forms of silicicfluoride of calcium. (In regard to the latter, however, it must not be overlooked that it is often necessary to adjust the microscope very carefully till the field of vision becomes dark, when the thin section specimen is most plainly visible).

In thin sections of andesine, which have been treated with hydrofluosilicic acid, beautiful hexagonal prisms of silicicfluoride of sodium .are found, besides characteristically developed forms of siliicicfluoride of calcium.

In the varieties of andesine richest in lime the forms of both silicicfluorides appear to preserve, tolerably well, their quantitative relations, while in labradorite the silicicfluoride forms of calcium are in excess. And calcium appears in just so much greater degree in anorthite as it contains less of sodium. It will not be superfluous to remark here that the smaller the quantity of sodium present which is successful in development, the more easily the feldspar specimen is decomposed by hydrofluosilicic acid.

In order to be able to determine the individual members of the feldspar family as exactly as possible let a comprehensive series of the most important of these members—for which exact chemical analyses have been made—be prepared, which will give a clear view of the various quantitative proportions of the silicicfluoride forms of calcium and sodium in feldspars, obtained by the action of hydrofluosilicic acid; and let this series of preparations be used for comparison with every new specimen. Then will one be in a position to judge with which preparation the specimen under investigation coincides most perfectly and so to which feldspar branch it stands most nearly related. Moreover the feldspar specimens represented upon Plate I, Figs. 17–20, afford some interesting points.

*b.* Distinction of apatite from nepheline.

For the distinction of these two very similar minerals Streng has given us[1] perfectly satisfactory methods in thin sections, founded upon the application of molybdate of ammonium mixed with nitric acid and of concentrated muriatic acid as reagents. Hydrofluosilicic acid also gives satisfactory results.

The cross sections of nepheline become darker than those of apatite through the separation of the silica and the presence of numerous crystals of silicicfluoride of sodium, sometimes also silicicfluoride of potassium, while around the apatite may be noticed clusters and groups of striated long prisms and needles of silicicfluoride of calcium with the characteristic etchings. (Plate II, Fig. 16.)

*c.* Distinction of the minerals: enstatite, bronzite, hypersthene and diallage.

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[1] Tschermak's Mineralog. Mittheilungen, 1876.

All these minerals are characterized in their thin sections by a common feature, a parallel, sharply rectilinear, very close grooving and a slight dichroism, and may therefore give cause for confounding them; but treated with hydrofluosilicic acid they can easily be distinguished by the silicicfluoride crystals of the newly formed products.

Upon diallage the silicicfluoride of calcium and also those of magnesium and iron appear numerously. In the other minerals only the silicicfluorides of magnesium and iron are to be noticed. And if these are treated with chlorine gas or with sulphide of ammonium gas the quantitative proportions of the silicicfluorides of magnesium and iron can be estimated, so that one can judge which of the three minerals he has before him.

*d.* Distinction of amphibole and biotite in thin sections.

Although amphibole and biotite at first sight can be easily distinguished from each other it is not always the case in thin sections. For the thin sections of both minerals have often similar outlines and are usually marked by the same color and by parallel, rectilinear grooving, and always by strong dichroism. But after treatment with hydrofluosilicic acid silicicfluorides of magnesium, iron and calcium appear upon the amphibole thin section, and silicicfluorides of magnesium, iron and potassium upon the thin section of biotite.

*e.* Distinction of lithia-mica, lithia-iron-mica and ordinary potassium-mica or muscovite.

These three varieties of mica can scarcely be distinguished by crystallographic or by optical properties.

If, however, they are treated with hydrofluosilicic acid, there appear upon the surface of the lithia-mica (for example from Roznau, in Moravia) very tiny, six-sided pyramids of silicicfluoride of lithium, sometimes distorted by an abnormal development of two planes, which in the second variety of mica (for example, lithia-iron-mica from Zinnwald) are accompanied by crystals of silicicfluoride of iron. Upon muscovite (for example an ordinary potassium-mica from Greenland) only solitary hexahedral crystals of silicicfluoride of potassium can be noticed. Especially do these varieties of mica belong to those minerals which are acted upon with the greatest difficulty by hydrofluosilicic acid.

## II. APPLICATION OF FLUOHYDRIC GAS FOR THE IDENTIFICATION OF ALKALI METALS IN SILICATES, ESPECIALLY IN THOSE WHICH ARE ONLY SLIGHTHY AFFECTED BY HYDROFLUOSILICIC ACID.

### *Principle of the Method.*

If a silicate is treated with fluohydric gas, its metals will be changed into silicic fluorides, single or double fluorides, of which one can easily become convinced by observing the fermentation[1] when the specimen is further treated with concentrated sulphuric acid.

By the action of hydrofluoric gas upon alkaline silicates silicic fluorides of the alkalies are formed, which, extracted with boiling water, can be brought to crystallization by evaporating the solution to one drop and placing this upon the object-glass, and can then be observed under the microscope. These forms are not essentially different from those produced by hydrofluosilicic acid.

In this way the most positive determination can be made for the smallest quantity of alkali in silicates, especially of potassium.

If the specimen treated with fluohydric gas and afterward boiled down in water contained alkaline earths besides the alkalies, usually only a small portion of the alkaline earths is dissolved, in the form of silicic fluorides in the aqueous solution, the larger portion remaining in the specimen.

Several experiments which I made upon feldspar specimens for the purpose of separating all the alkalies of that part of the specimen changed by the fluohydric gas as silicic fluorides and retaining in the specimen the greater portion of the calcareous earths as a fluoride, led approximately to this rule: That the specimen (of 2—6 □ $^{\text{mm}}$ D.) treated with fluohydric gas should be boiled upon a platinum dish (of 45 $^{\text{mm}}$ D,) filled with water, as many minutes as the upper surface of the specimen contains □ mm. And the calcium fluoride remaining in the specimen can then be dissolved in concentrated sulphuric acid and made visible in the form of gypsum crystals so that its quantitative relation to the alkalies can be estimated.

But if the specimen treated with fluohydric gas contains only alkalies (and no alkaline earths) then, after a complete removal of the silicic fluorides of the alkalies (by boiling away in water), on further treatment of the specimen with sulphuric acid no fermentation and especially no devlopement of fluohydric gas is observed.

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[1] As a result of the development of hydrofluoric gas and silicic fluoride at the same time.

Before I was certain of the application of hydrofluo silicic acid, as the most suitable reagent for the determination of individual metals in minerals, I used fluohydric gas and sulphuric acid for the detection of single members of the feldspar family and in the following manner:

After I had taken all the silicic fluorides from that portion of the specimen changed by fluohydric gas by means of boiling with water, I allowed these silicic fluorides to crystallize upon an object glass. I then decomposed the calcium fluoride remaining in the specimen by means of sulphuric acid, and allowed the calcium sulphate to make its appearance on a second object glass in the form of gypsum crystals. By comparing the quantitative proportions of the crystals of silicic fluoride and the gypsum crystals I was able to draw a corresponding conclusion regarding the quantitative relations of the alkali metal (sodium) to calcium.

Moreover, I sometimes tried the following plan: I treated two specimens of an equal size, and equally changed by fluohydric gas, with equal drops of sulphuric acid, one piece after the other, after the boiling with water, and noted in each case (*a*) the continuance of effervescence, or development of gas, and (*b*) the quantity of gas bubbles developed, enclosed by sulphuric acid.

From the relations of the data preserved, I was able to draw a correct conclusion regarding the quantitative proportions of sodium to calcium in oligoclase feldspar; for by treatment of the specimen, changed by fluohydric gas, with sulphuric acid before boiling away with water, all the fluorides were decomposed, while by treatment after boiling away with water, only the undissolved calcium fluoride remained for separation.

Experiments made upon a specimen of chiastolite with fluohydric gas, showed through the effervescence of the specimen in sulphuric acid that the clay was also changed into a fluoride, which was dissolved in water but not crystallized.

## EXECUTION OF THE METHOD.

*Apparatus for the development of fluohydric gas and for the reception of the specimen.*

In order to develop the fluohydric gas and cause it always to act upon the thin section or specimen of whatever kind, I use a platinum crucible of the size of Fig. 1. In the crucible is a frame of platinum wire which supports a platinum plate pierced with an annular opening, with upturned edges; the margin of the plate and one circular opening in the center also have upturned edges. This plate serves for the reception of the specimen.

Fig. 1 represents a section of the crucible with the frame and plate, and Fig. 2 the surface of the plate.

Fig. 1.

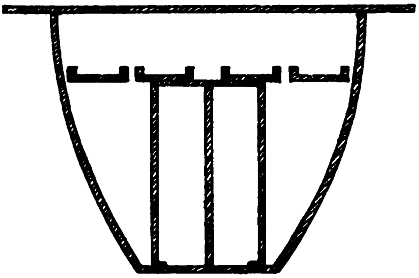
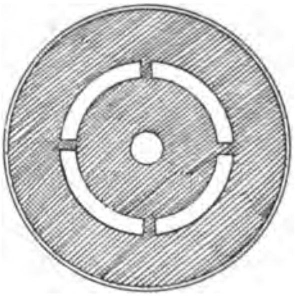


Fig. 2.



Instead of the plate a narrow strip of platinum may be used to receive the specimen.

For covering the crucible I use a circular piece of platinum which extends over the edge of the crucible, and is furnished, upon that side which is next the crucible, with a coating of wax (to be warmed before each experiment), in order to make it adhere firmly to the crucible. To assist in this, a weight is laid upon the piece of platinum acting as cover.

The thin sections or pieces to be investigated are so placed upon the platinum plate (or strip of platinum,) that little spaces are left between them so that a greater or less number (from 10 to 20) of specimens, according to their size, can be exposed at once to the action of fluohydric gas.

Only, at this point, it is necessary to note the relative positions of the specimens in order to avoid errors in subsequently confusing them.

*Treatment of the specimen with fluohydric gas.*

On the floor of the platinum crucible, scatter a half gram of pure finely powdered fluoride of barium,[1] place the platinum frame in position and pour upon the inner surface of the crucible enough concentrated chemically pure sulphuric acid to entirely cover the fluoride of barium; then sieze quickly (because the escape of fluohydric gas has already begun) with a pair of pincers the turned up edge of the platinum plate carrying the specimens, lay this upon the frame of platinum wire, cover the crucible with the above mentioned waxed platinum cover and place a weight upon it in order to hold the platinum cover firmly over all.

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[1] Mercantile fluoride of barium needs to be mixed with barium chloride or sulphate of baryta.

The entire apparatus covered with a glass tumbler or an inverted beaker may now be left standing in any convenient place.

If a strip of platinum has been used for holding the specimens instead of the platinum plate, sufficient space must be left next the strip for the sulphuric acid to be poured in after the introduction of the specimens into the crucible, in which case it is necessary to close the crucible as quickly as possible to prevent the escape of the fluohydric gas into the air.

In order to allow the fluohydric gas to act upon the specimen as long as possible I am accustomed to leave the apparatus closed until the second day, when it is opened in a draught cupboard.

After the settling of the fluosilicium and the removal of the superfluous fluohydric gas, the platinum plate with specimen is taken out and the specimens closely examined to see if any of them are spotted by the effervescence of the fluoride of barium or by the sulphuric acid.

### *Boiling away in chemically pure water of the specimen changed by the action of hydrofluoric acid. Extraction and crystallization of the silicic fluorides of the alkalies. Their appearance under the microscope.*

Cut from the thin section acted upon by hydrofluoric gas a specimen of 3—6 □ $^{\mathrm{mm}}$, or if the specimen acted upon was a fragment, cut a piece of the size of a small pea and lay it in a perfectly clean platinum dish, fill the latter with chemically pure water, take it up with iron tongs and hold it in the flame of a spirit lamp until the water has boiled at least as many minutes as the surface of the specimen contains □ $^{\mathrm{mm}}$. By gentle movements of the vessel take care that the specimen moves about in the water.

After the boiling remove the specimen from the water with perfectly clean pincers, wash it with water and lay it one side upon an unused object glass.

Evaporate the aqueous solution at not too high a temperature to one large drop, place this upon the thin (hard) balsam surface of an object glass and let it dry in a place free from dust.

During the drying the silicic fluorides separate in beautifully formed crystals which, after complete drying, can be examined with the microscope (most successfully when magnified to the 400th power.)

*The silicic fluoride of potassium* appears in hexahedrons, which, at times, form splendid cruciform or chandelier-like groups, or in combination forms of the hexahedron with the octahedron, or of rhombic dodecahedron with the hexahedron. Often these are imperfectly formed crystals of the tesseral system, distorted in the line of the axes; but their opacity between the crossed Nichols seems to easily distinguish them from the silicic fluorides of all other metals, (unless it be the similarly formed silcic fluorides of metals that occur very infrequently: cæsium, rubidium, thallium.)

*The silicic fluoride of sodium* appears in hexagonal prisms which are terminated by basal planes, or by a blunt pyramid, whose vertical edges are sometimes blunted by the narrow planes of a secondary prism. Yet quite often regularly formed crystals of silicic fluoride of sodium, barrel-shaped, oval, elliptical and cylindrical forms, which belong to the same silicic fluoride metal, are found near these.

From all the specimens of oligoclase feldspar, I obtained near the above mentioned forms of sodium, a small quantity of long pointed needles, or long thin four sided prisms terminated by a couple of inclined planes, which I think I may regard as silicic fluoride forms of calcium, since the above mentioned feldspar contains, besides sodium, calcium and aluminium, no other constant metal, and since from pure clay silicates (chiastolite and kaolin) no silicic fluoride appeared in such needles and prisms, yet I always found these forms in small quantities in anorthite and wollastonite.

*The silicic fluoride of sodium*, prepared from the specimen of oligoclase feldspar, appeared commonly in imperfectly formed, barrel-shaped, oval and cylindrical crystals, which sometimes, having pierced through the striated mass of needles and prisms of silicic fluoride of calcium, presented splendid groups.

### *Treatment of the specimen boiled in water with sulphuric acid*

Near the specimen, freed from silicic fluorides by boiling in water, and which has been laid upon an object-glass, place one or two drops of sulphuric acid and lay over it such a cover-glass that the specimen will be covered with the acid. Now observe (eventually also in the microscope) whether gas comes off or not. If no gas is formed then heat the object-glass gently some ten or fifteen seconds, touching the point of the flame of the spirit lamp with the edge of the object-glass.

If no gas is developed in the last named case, there are no metallic fluorides existing in the specimen boiled with water.

If, for example, the specimen was a member of the feldspar family, and if the aqueous solution has shown only silicic fluorides of the alkaline metals, then one may be certain that the specimen is a pure potassium or natron feldspar (orthoclase sanidine or microcline, or albite, or pericline, according as the silicic fluoride crystals obtained belong to potassium or sodium). If only a very weak gas development is noticed in the feldspar specimen boiled with water, and the specimen is very thinly covered with gas bubbles, or surrounded by a thin, spongy bubble-wreath, then one may assume that he has examined a member of the oligoclase series. But if a strong and continuous development of gas and of gas bubbles occurred, then one has,—according to the quantity of silicic fluoride crystals of sodium obtained from the specimen—a member of the andesine or labradorite series. Anorthite may in most cases be recognized by treating the feldspar specimen before boiling with water, since it shows no effervescence, but only a slow but strong development of tolerably large bubbles of gas is noticed, while all oligoclase feldspars treated with hydrofluoric gas effervesce in sulphuric acid, the more energetically the more soda they contain.

In order to estimate correctly the proportion of sodium which has been obtained in the form of silicic fluoride crystals, to the calcium fluoride remaining in the specimen, pour off the drop of sulphuric acid with the rest of the specimen from the object glass, into a clean platinum dish, remove the specimen and evaporate the sulphuric acid by heating the platinum cover. Dissolve the residuum which may be left in a large drop of water, place it upon a clean object glass and allow it to dry. From the quantity of gypsum crystals formed, which can now be examined upon the object glass, by aid of the microscope, in proportion to the quantity of silicic fluoride crystals of sodium, which one has obtained from the aqueous solution, a safe conclusion can be arrived at as to which series the feldspar specimen belongs to.

*Remarks on the application of hydrofluoric gas for purifying turbid thin sections, bringing forth clearly the mineral outlines as well as the mineral structure, and on the identification of colorless inclusions in colorless minerals.*

It frequently happens that thin sections of rocks which have attained the greatest possible thinness are still unfit for microscopic investigation by the presence of several dark mixed substances disseminated through the entire mass. In such cases the petrologist must next solve the problem of how to remove the dark substances without crumbling the section.

In my earlier work I used hydrochloric acid for this purpose. I fastened the turbid thin section to an object-glass by means of Canada balsam, and let it lie in a little cup containing hydrochloric acid several hours or days, according to the acid's action on the thin section. But since the balsam plate under the thin section became dimmed and opaque by the hydrochloric acid, I put upon the other cleaned and dried half of the object-glass some new balsam, to which I gave by heating the necessary consistency, and shoved over upon it by careful warming, the easily freed thin section. I could now cover it with a new balsam layer and apply a cover-glass, as is customary in preparing a thin section for investigation.

In this way I obtained satisfactory results. Thus, for example, I succeeded in removing the calcite from the dark thin sections (quite unfit for microscopic study) of grayish white calcareous aphanite (diabase amygdaloid) from Krusná Hora, near Beraum, and then with the thin section, now quite transparent as well as perforated, in proving that the original substance of the calcareous aphanite is identical with the greenish black heavy diabase of the same locality.

Fluohydric gas also renders similar service, if the thin section is either first boiled with water or treated with sulphuric acid according to its mineral properties. Thus the thin sections of a compact porphyry, quite opaque but thin as paper, on treatment with fluohydric gas and subsequent boiling with water, became quite clear and bright and the fragile feldspathic forms scattered through the close quartz grains were readily recognized; moreover sections of nepheline phonolite, dark but thin as paper, required besides treatment with fluohydric gas and water, sulphuric acid in order to become perfectly clear and transparent.

An interesting appearance presented itself to me in a thin section of phonolite from the Wachholder Mts. at Teplitz, where the ground mass consisting of a homogeneous polarizing substance (without recognizable outline) is, after successive treatments with hydrofluoric gas, sulphuric acid and water, resolved into rectangles and hexagons of nepheline. And upon this section of nephline appeared a significant scaly structure of which nothing was before noticed. It is evident that Möhl's nepheline-glass was represented here in plain sections.

Before Des Cloizeaux's epoch-making works, "Mémoire sur l'existence, les propriétés optiques et cristallographiques, et la composition chemique du microcline etc." (Extrait des Compt. rendus, etc. t. LXXXII, 17. Avril 1876; and Extrait des Ann. de chimie et de Phys., 5th séries, t. IX., 1876) were by the kindness of the distinguished author placed in my hands, I had already observed the characteristic microstructure of amazonite from Miask, and of microline from Karlsbad[1] (from the systematic collection or the Bohemian museum, with the label "orthoclase [white, transparent laminated] from Karlsbad"), and upon the ground of the changes effected by hydrofluoric gas and water, I judged that internally or structurally different laminæ are present; but I also found in many oligoclase feldspars laminæ which under the influence of the above named reagents showed a substantial difference.

## III. Application of Chlorine Gas for determining the Insolubility of Minerals in Acids, the Gelatinous Nature of Silicic Earths separated from the thin sections of many Silicates, and for the Determination of Alkalies, Alkaline Earths and Iron-Protoxide.

*Development of Chlorine Gas, and treatment of the specimen with it.*

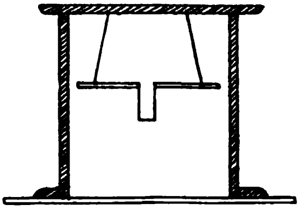

Fig. 3.

For developing chlorine gas I use a glass vessel (somewhat of the form represented in Fig. 3), upon the bottom of which is evenly scattered finely powdered manganese in the form of a ring an inch in width, and moistened with muriatic acid. Two strips of glass will serve to hold the mineral and thin-section specimens. These strips should be cemented to the upper side of a glass stopper on either side of the handle (as illustrated in Fig. 3), and by means of the stopper lowered into the middle of the glass vessel from whence they can be easily withdrawn when the operation is completed.

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[1] The microstructure of the Karlsbad microcline corresponds quite well with that which Des Cloiseaux in his above named works (p. 8, fig. 12) describes as a microcline from Australia (?).

But if microscopic silicicfluoride crystals which are upon an object-glass, are to be exposed to the action of chlorine gas, then a low uncovered porcelain crucible may be used to support the object-glass.

When the frame carrying the specimens has been placed in the glass vessel and the latter closed as tightly as possible with a glass plate, whose edge has been rubbed with grease, then place the glass vessel upon a wire netting over a spirit-lamp and heat it till gas has developed rapidly for five minutes.

Special care must be taken while heating this that no large bubbles form lest by their bursting, the specimen should be soiled.

After about five minutes development of gas, the vessel should be taken from the flame and, with its cover, left standing twenty-four hours upon the work-table; but during this time the heating (for the development of a new portion of chlorine gas) may be repeated, as often as the nature of the mineral under investigation may require.

After the action of the chlorine gas has lasted about twenty-four hours, the frame, (the glass stopper) with the specimens, is taken out. each specimen laid upon another object-glass (with the side acted upon uppermost) and subjected to microscopic examination.

If the presence of (liquid) chlorides of the alkaline earths (calcium and magnesium) as new formations, is expected and it is wished to obtain them in characteristic crystalline forms, it is advisable to place the object-glass holding the specimen in a drying dish for the complete drying of the specimen, then to immediately enclose it in Canada balsam and place it under a cover glass.

If microscopic silicic fluoride crystals (upon an object-glass) are exposed to the action of chlorine gas, from three to five minutes of this action is sufficient to bring out the characteristic changes upon the silicic fluoride crystals; then the object glass is to be taken out, thoroughly cleansed and the changed crystals examined under the microscope.

*Proof of the insolubility of a mineral in acids.*

For testing the insolubility of certain minerals of a mixed rock in acids, the specimen in the form of powder was usually boiled in hydro-chloric acid, shaken and left standing for some time. Then the changed specimen was investigated by microscopic observation and compared with fresh material for the purpose of establishing which minerals were wholly decomposed, which in part and which remained undecomposed.

Although the recognition of half-decomposed minerals in their tiny fragments under the microscope was often attended with difficulty, still these methods led in many cases to the desired result, provided the strength of the acid, the continuance of its action and the temperature by which the action was accompanied received proper consideration in proportion to the effect obtained upon determined minerals of the specimen.

Especially important was the fulfillment of these conditions, if the specimen was treated in the form of a thin section, since in this case a complete decomposition of the mineral had not been sought but only a clear change upon its (the thin section's) upper surface (evident mainly along the edge and in the clefts).

In the investigation of the insolubility of minerals in acids when occurring in crystalline rocks, it was found profitable to lay the thin section fastened to the object glass by Canada balsam in a little cup having a smooth bottom, in which has been placed, according to the requirements, hydrochloric acid or aqua regia; to leave it in this several days in perfect quiet, and then, after removing the acid from the specimen by careful immersion in chemically pure water, (the object glass being in a horizontal position) and drying with great care, to subject it to microscopic examination; for by this process it was possible not only to observe the decomposition of many minerals by means of the changes on their upper surfaces, but also to determine the nature and quantity of the silica separated from the silicates.

If the lower part of the specimen on the balsam plate has become, by the action of the acid, dark and opaque it can by careful heating be loosened and slipped upon a new balsam plate placed upon the same object glass.

Instead of all these methods for determining the insolubility of the several minerals in a thin section, I believe a new one may be presented as the most useful, namely, that which is based upon the action of chlorine gas upon thin sections of rocks and minerals.

According to this method the thin section specimens are laid upon the glass strips of the frame (glass stopper) in fig. 3, page 36, as close to the edge as possible but not so close together as to touch and in the manner described above (pages 36 and 37) exposed for about twenty-four hours to the action of chlorine gas. After being taken out of the apparatus each specimen is placed upon a new object-glass (arranged with the treated surface uppermost) and examined in the microscope.

If the thin section is spotted upon its upper surface with drops of chlorine water—which usually occurs with minerals which separate much gelatinous silica—the specimen may be dried in the exsiccator.

With the microscopic investigation here proposed, for which previous experiments upon determined minerals must be laid down as a guide for the determination of the decomposition of a thin section of mineral by means of chlorine gas (under the above mentioned conditions) the following points must be observed: (*a*) the nature and quantity of the silica separated out of the silicates, (*b*) the quantity of the chlorides formed upon the upper surface of the mineral, (*c*) the nature and strength of the etchings effected by the chlorine gas.

The following may be taken as a general rule: *The more the silica that has separated from a silicate, the more the chlorides that have formed and the more strongly marked the etchings, so much the greater is—under a like condition—the decomposition of the mineral.*

### *Determination of the gelatinous nature of the silica separated upon the upper surface of silicates.*

If one has observed in the microscope the gelatinous silica separated by chlorine gas, upon the surface of some minerals, for example, nepheline, elaeolite or olivine, and has distinguished it from the powder-like silica of some minerals, he is in most cases able to determine whether the silica separated upon another mineral, is of a gelatinous or powder-like nature.

In order, however, to determine in every case with certainty the nature of the silica, the method proposed by Behrens, which is based upon the capacity of gelatinous substances for absorbing coloring matter, is strongly recommended.

I make use of this peculiarity of gelatinous substances in the following way: I cover the thin section treated with chlorine gas and placed upon a clean object-glass with a drop of fuchsin-solution, and after some time I lay the object-glass with the thin section upon it in a crucible filled with chemically pure water.

If there is no gelatinous substance upon the upper surface of the thin section, the color of the thin section vanishes in a very short time, since the coloring matter mentioned is very easily soluble in water, but if there is gelatinous substance upon the upper surface of the thin section then every smallest part of the gelatined silica will be affected by the red fuchsin solution, which cannot be removed from gelatinous substances by water.

In this process, care should be taken that the thin sections be thoroughly cleansed before the treatment with the chlorine gas and that no portion of the silica be spilled from the surface of the thin section into the water by the movement of the object glass. While the latter condition is very easily fulfilled by a careful carrying out of the operation mentioned, the former usually requires a suitable cleansing of the thin section with alcohol or better still with chloroform, since the least trace of Canada balsam which remains imbedded in the crevices of the thin section may produce the same result as gelatinous silica.

This method is excellent *for distinguishing nepheline from apatite* and from monoclinic feldspar forms, and equally so for *distinguishing hauyne* and *nosean from leucite.*

The application of this process upon the thin sections of various kinds of rocks, especially upon the thin sections of basalt from Schlanberg and of nepheline phonolite from the Wachholder mountains at Teplitz is very satisfactory. The thin sections of the first rock, magnified to the four hundredth power, showed intense red olivine, nepheline and hauyne flakes in regular arrangement between augite groups, and numerous, colorless apatite sections, while on the phonolite thin section, the quantity of sanidine tablets remaining colorless between the red nepheline sections could be easily examined and determined.

### *Preparation and examination of the chlorides formed by the action of chlorine gas.*

By the action of chlorine gas upon a silicate which contains alkalies and alkaline earths, and which suffer decomposition by means of the above mentioned reagent, metals of the alkalies or alkaline earths are, in the changed portions of the silicate, produced in the form of chlorides which appear upon the surface of the fragment of thin section in more or less perfect crystals.

The chloride of sodium very readily crystallizes. Its cube shaped crystals and step-like structures are best seen in those silicates which separate powder-like silica (as for example, andesine, labradorite), but far more numerous do they appear upon those silicates containing soda (as elæolite), but they lie imbeded in the silicic gelatine and are more or less covered with it.

In order to determine the sodium chloride crystals in the last named case, it is advisable to cover the specimen with a solution of Canada balsam in chloroform and to supply it with a cover-glass; for in this way the silicic gelatine becomes strongly pellucid and shows the colorless cubes of sodium chloride. The chloroform, moreover, seems to cause the sodium chloride left in solution in the gelatinous silica to crystallize.

Less easily does the chloride of potassium, which is isomorphous with sodium chloride, crystallize. And, to cause the rhombohedral prisms ($\infty$ R. R.—R. 0R) and tablets of calcium chloride ($Ca\ Cl_2 + 6H_2\ O$), and chloride of magnesium ($Mg\ Cl_2 + 6H_2\ O$), which liquify on exposure to air, to crystallize upon mineral thin sections by treatment with chlorine gas, is most difficult of all.

The forms of the two last named substances, which usually present distinct crystals only under the exsiccator, are generally spherical, elliptical or cylindrical, if they are successful in formation.

From the ferruginous silicates, which suffer decomposition on treatment with chlorine gas, appear often chlorides of iron. But since they belong to substances most soluble on exposure to air, they will not appear clearly in crystal forms upon the mineral thin section, but appear as a half-liquid pigment upon the mineral from which they are derived, gradually impregnating the adjoining portions of the thin section. Thus, from ferrous chloride as well as ferric chloride may proceed the intense yellowish-green or greenish-yellow color which appears upon the colorless or pale yellow olivine section, or upon other minerals containing iron protoxides, if they are exposed to the action of chlorine gas.

### *Judicious use of Streng's methods for the identification of apatite in thin sections, and especially after treatment with chlorine gas.*

In order to determine apatite in thin sections of rock, [1]Streng has made the practical suggestion that the thin section, placed upon an object-glass, be treated first with hydrochloric acid (to dissolve the apatite) and then with molybdate of ammonia (diluted with nitric acid until the white precipitate again dissolves), then furnished with a cover glass and studied under a microscope. From the quantity of tiny but shapely formed citron-yellow crystals (magnified to the 400th power) which I have usually regarded as rhombic dodecahedrons, (rarely octahedrons) of the tesseral system, the quantity of phosphate (apatite) appearing in the thin section can usually be determined in similar proportions.

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[1] Tschermak's Mineralog. Mittheilung. 1876.

Since apatite, like every other phosphate, is more or less affected by chlorine gas, the thin section treated with chlorine gas, in which one has already microscopically studied the decomposition of the minerals, can, for the determination of the phosphoric acid, be treated with one or more drops of molybdate of ammonia[1] diluted with a corresponding amount of nitric acid, and furnished with a cover-glass for microscopic examination; eventually, also, inclosed in Canada balsam applied at the edge of the cover glass.

The result is in general the same as that shown in the first paragraph; but in particular it is to be observed that if silicates which have separated gelatinous silica exist near rich apatite in a thin section, they are just as much impregnated with the citron-yellow substance of the phospho-molybdate of ammonia compound, as with the red fuchsin solution. Thus the reaction under these conditions serves a double purpose: (*a*) the proof of the existence of a phosphate in the thin section, and (*b*) the proof of the gelatinous nature of the silica separated from a silicate.

## IV. THE PRODUCTION AND OBSERVATION OF ETCHINGS, AND THEIR IMPORTANCE IN THE DETERMINATION OF MINERALS IN THIN SECTIONS.

In the introduction (page 6), all those works were specified which treat of the representation of etchings upon various surfaces of many minerals and of their crystallographical significance. But at the same time the remark was made, that up to the present time no decided step had been taken to turn to account these etchings for determining the individual minerals in thin sections.

I am unfortunatelv unable to describe a large series of favorable results; for only upon the thin sections of a few minerals have I observed perfectly characteristic and, according to the above methods, easily presented etchings, which show finely the structure of the crystals of the individual minerals. But the thin sections of most minerals treated with hydrofluo-silicic acid or hydrofluoric gas, or chlorine gas, show upon their upper surfaces changes produced by etchings, which, although hardly definable in words, present to the observer not an accidental appearance, but one closely connected with the inner structure of the mineral, so that in most cases their examination seems to be of value.

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[1] The superfluous molybdate of ammonia crystallizes upon the object-glass in colorless needles.

Since the nature of the etchings—by which term I believe it is allowable to indicate all depressions and protruberances in any degree characteristic, produced upon the mineral section by a chemical reagent—depends upon the crystallographical condition of the mineral section, various etchings naturally appear upon the various sections of the same mineral; and this furnishes us with a reaction which sometimes is not unimportant in the determination of a mineral.

It is to be noticed that with the appearance of the etchings on mineral sections new products also appear by the action of the chemical agents, or substances (like silica) are separated, which cover the etchings more or less wholly and must therefore be removed if the etchings are to be clearly studied.

If the new formed products are silicic fluorides or chlorides their removal from the surface of the thin section can be secured by repeated boiling in water, which can be conveniently done upon a platinum lid. And by the mechanical action of the boiling water the silica which may have separated is usually washed away from the surface of the thin section. If the new formed products are fluorides of alkaline earths which are insoluble in water they can be dissolved by sulphuric acid and then removed by water. But in the latter case it must be noticed that the action of the sulphuric acid upon the surfaces of many minerals results in additional etchings.

In order that the surface of an etched mineral section freed from new formed products and thoroughly cleansed may be conveniently observed under the microscope it should not be covered with Canada balsam but, if the section is to be preserved in the form of a microscopic preparation, a cover glass should be at once placed upon it, and the edge of this cemented to the object-glass by Canada balsam or some similar substance, the proper consistency being attained by heating on an object-glass.

1. *Etchings produced upon the surface of apatite.*[1]

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[1] Borloky. Sitzungsber, d. k. Böhnn. Ges. d. Wissemsch, V. 9 Feb., 1877.

*a.* By action of chlorine gas.

By the action for twenty-four hours of chlorine gas upon thin sections of apatite from Schlackenwald, the sections being cut parallel with the basal planes, their upper surface (magnified to the 400th power) was changed into an aggregate of apparently hexagonal crystals, thickly crowded together and clinging to each other (subindividual crystal molceules) (P or P. 0 P or 0 P. P) which were placed for the most part perpendicular to the basal planes or showed only a slight inclination toward them.

In the outer zones the crystals were of various sized diameters and distinguished for the most part by prominent basal planes, but the boundary lines of the outer zone were sharply defined by crystals closely crowded together, of almost an equal size and exactly parallel to the crystal outline, running out, for the most part, into pyramidal points, so that a more splendid illustration of inner crystal structure could hardly be expected from any other chemical agent. (See Plate II, Figs. 19 and 20.)

Above the crystals there sometimes lay a mixture of short needle-shaped forms whose horizontal projections toward each other, showed for the most part an inclination of 60° or 100° and which I thought could be considered the remaining edges of the vanishing crystals of the upper layer. And these crystal-needles appeared most clearly when the thin section was covered with Canada balsam and furnished with a cover glass.[1] (See Plate II, Fig. 18). On the other hand the crystals situated beneath (the subindividual crystal molecules) could hardly be perceived through the Canada balsam.

Upon the thin section of the same apatite, crystals cut almost parallel to the prism surface (∞ P) which were boiled for a few seconds in aqua-regia, there appeared plainly in some places rhomboidal lateral angles, showing for the most part a splendid scale structure, while the rest of the thin section showed regular rhombic figures or rhombic figures long drawn out, and laterally truncated, parallel and crowded together or closely behind each other, (see Plate II, Fig. 17.)

The etchings of the apatite thin section boiled several minutes in water in a platinum dish were not injured but the tiny crystals appeared still more beautiful and clear; only the tiny needles (probably edges remaining from the upper layer) were scarcely visible.

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[1] Upon which bubbles of air were noticed almost continually.

Upon the natural surfaces of apatite—probably on account of greater insolubility—the abovenamed etchings were not noticed. There appeared upon the prism surfaces sharp grooves of varying lengths, and three cornered and trapezoidal forms. And upon a few places only were seen isolated rhomboidal angles (the lateral angles of tiny pyramids).

*b.* By action of hydrofluosilicic acid.

The etchings produced upon a thin section of apatite, cut parallel to the basal plane, by action of hydrofluosilicic acid, though only appearing plainly after the removal of the quantity of silicic fluoride of calcium formed. (removed by boiling in $H_2O$), showed (magnified to the 400th power), no material difference from the etchings which were described in the preceding paragraph, as being produced by chlorine gas. Yet in many places the peculiarity was to be noticed that the subindividual crystal forms of the principal basal surface with the pyramid, appeared composed of the regular crystal scales or of step-like crystals built up according to the hexagonal tablet as (0P. P) being always smaller above. Figure 16, plate II shows the silicic fluoride of calcium and the etchings produced upon the basal plane of an apatite crystal by the action of hydrofluosilicic acid.

*2. Etchings upon a thin section of olivine, produced*

a. By hydrofluosilicic acid.

The etchings produced by the action of hydrofluosilicic acid upon a thin section of olivine from Kozákov (at Turnau) and freed from the silicic fluorides of iron and magnesia by boiling with water (when magnified to the 400th power) are very regular crystal forms, closely crowded together and perfectly parallel to each other, of the pyramidal or tablet-shaped habitus, which latter, if they are not perfectly formed or not clearly visible, resemble rhombic figures overlying each other or clinging together.

By the individual crystals of pyramidal forms, a pinacoid or a dome may seem to be combined in the same zone with the predominant rhomboidal pyramid, while on the tablet-shaped crystals near the principal pinacoid a pyramid, prism or dome may appear not falling in the same zone with the pinacoid.

Magnified to the 400th power these subindividual crystals attain in some olivine sections the size of barleycorns; upon other sections they appear only like pinheads furnished with two sharp and two blunt corners, and arranged regularly upon the entire section, (See Plate II, Figs. 11 and 12,) upon which the silicic fluorides are also shown near the etchings.

b. By the action of chlorine gas.

The etchings produced by chlorine gas upon thin sections of olivine from Kozákov are mostly short; not rectilinearly bounded, but usually perfectly parallel grooves, among which short pointed prisms or pointed rhombic figures were found in a very few places.

3. *Etchings upon thin sections of dichroite produced by action of hydro-fluosilicic acid.*

The etchings observed upon the thin sections of dichroite (from Bodenmais and from Orrijaerfvi in Finnland) were for the most part short rectangular depressions either parallel througout or one lying almost at right angles to another, between which were found more or less regularly laid grooves of various lengths. Only in a few places were the latter predominant; moreover among the regular some isolated depressions also appeared which showed much similarity to the crystal forms of dichroite represented in Naumann's Elements of Mineralogy (1871, p. 404). (See Plate II, Fig. 10, in which, for the most part irregular etchings are represented near the silicic fluorides).

4. *Etchings upon thin sections of chiastolite produced by the action of hydro-fluosilicic acid.*

In the thin sections of a chiastolite crystal (from an unknown locality) which were cut parallel to the basal planes, a charry substance appeared in more or less thickly packed particles, not only in the central part (along the crystallographical axes), upon the vertical lateral edges and along the diagonal of the thin section, but also in other parts of it and indeed in featherlike ramifications which ran out from the diagonal parallel to the edges of the oblique crystal section. The chiastolite substance appeared to be somewhat homogeneous, without showing anywhere a special micro structure except the imperfect cleavage crevices and a few small almost wholly colorless spots.

But after treatment with hydro-fluosilicic acid the imperfect-cleavage crevices appeared like broad spotted veins which were traversed with very broad undulating fibrous border zones, and enclosed little irregular rhomboidal, colorless spaces, so that the most important part of the thin section was marked by a strong spotted or undulatingly-fibrous structure.

Upon several points on the edge of the thin section appeared instead of the spots, promiscuously arrainged groups of long slender bands which—just like the spots and fibers produced from the chiastolite substance—presented the idea of a paramorphosis.

The colorless, somewhat less distinct rhomboidal spaces which may be considered as the residue of the unchanged chiastolite substance were cut by rare but quite perfect cleavage crevices which crossed almost at a right angle (90° 31' and 91°) and corresponded almost exactly with the cleavage directions of chiastolite (91° 4'). (See plate II, Fig. 13).

5. *Etchings on thin sections or cleavage fragments of hypersthene, broncite, diallage, augite, and amphibole produced by hydrofluosilicic acid.*

While the sections of hypersthene from Sky Island and of broncite from Graubat in Steiermark, treated with hydrofluosilicic acid, presented a union of fragile parallel fibres or very slender bands (see Plate II, Fig. 9, broncite from Graubat treated with $H_2$ Si $F_6$) the thin sections of diallage from the gabbro from Wolpersdorf showed usually two systems (cutting each other at a sharp angle) of less close but sharply rectilinear cleavage crevices between which groove-like etchings, much twisted and intertwined, appeared closely crowded together (see Plate II, Fig. 8). And these thin sections of diallage enclosed little broncite particles whose microstructure seemed uniform with that of broncite from Graubat.

Upon the thin sections of augite[1] and amphibole[2] which were cut parallel to the pinacoid face, only grooves of various lengths were noticed, which followed almost uniformly a fixed direction.

6. *Etchings on Lithia-iron-mica from Zinnwald, produced by the action of hydrofluoric gas and subsequent boiling with water.*

After treatment with hydrofluoric gas and water, there appeared upon the pale yellow or reddish white scale of this mica irregularly distributed, rusty-yellow flakes which often showed rhomboidal or six-sided incoherent outlines. And upon many places free from the rusty yellow flakes appeared very slender, more or less thickly congregated (depressed), rhombic figures, which were arranged for the most part parallel to the rhombic edges. (See Plate II, Fig. 14).

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[1] From Wartha on the Eger and from Kaaden.

[2] From Peperin basalts from Lukov at Millesohau (see Plate II. Fig. 7).

I have measured many of the acute and obtuse angles of these rhombic figures, but obtained very different results; for the acute angles 49° 30', 50°, 56° 30', 59° and 60°, and for the obtuse. 130° 30' to 120°.

*7. Etchings upon thin sections of scapolite from Malsjö in Wermland.*

Upon the thin sections of scapolite taken nearly parallel to the main axis and treated with hydrofluosilicic acid, the etchings which were observed between the strongly appearing grooves parallel to the main axis, resembled long, much distorted and overlapping grooves which were at times united into a snake-like net-work. Chlorine gas, likewise, produced very irregular, jaggedly roundish and longish depressions and caused cleavage grooves parallel to the main axis to appear strongly.

*8. Etchings upon thin sections of elaeolite from Laurwig in Norway, produced by chlorine gas (magnified to the 400th power.)*

After removing the mass of separated gelatinous silica and the crystals of sodium chloride imbedded in it, (usually these are octahedrons,) there appeared upon the thin sections of elaeolite a parallel rectilinear grooving, besides the rare but broad rectangular cleavage crevices. And in the band-shaped spaces between the grooves appeared long rectangular depressions and protuberances, sometimes pointed at one end or many-sided, and more or less regularly prism-shaped and parallel to the grooves. Among these in some few places, tolerably regular hexagonal prisms were observed. Upon one of these prisms a secondary pyramid appeared on one of the basal planes. (See plate II, Fig. 15).

*9. Etchings on a thin section of Leucite from Vesuvius.*

(Observed when magnified to the 400th power.)

Upon the leucite there appeared, after treatment with chlorine gas, very tiny and closely crowded, round or polygonal depressions, and after treatment with hydrofluo-silicic acid a very close, delicate polygonal network (See Plate II, Fig. 2).

*10. Etchings on thin sections or cleavage fragments of feldspar.*

(Magnified to the 400th power.)

After treatment with hydrofluoric gas and then with boiling water, the most perfect cleavage planes of sanidine from the phonolite of Tannberg (at Tollstein, formerly Kingdom of Rumburg) showed either long, polygonal, sometimes six-sided depressions (of the ordinary outline of the clinopinacoid face) or groove-like, very slender and close, parallel depressions. Those of adularia from St. Gotthard, and of ryacolite from Vesuvius, showed for the most part groups of parallel, pointed (tower-like) and wedge-shaped depressions. or more rarely rows of short prisms and cones, projecting sharply out of the etched surfaces.

After a similar treatment of microcline from Miask (amazonite) the characteristic microstructure appeared upon some of the cleavage planes (which were probably parallel to the basal plane) in the most beautiful manner, since the various internal and structual bands or parts were changed in various ways. But the microstructure of microcline appeared especially beautiful upon some cleavage planes of white striated feldspar (mentioned on page —) of the Bohemian museum which was labelled "Orthoclase from Karlsbad." Upon other cleavage planes of the same microcline (which were probably parallel to the klinopinacoid faces) there appeared closely crowded together and parallel, long, slender, spindle-like, cylindrical depressions, which by a gradual lessening of length were changed into scaly etchings arranged like tiles.

Upon the most perfect cleavage planes of albite from Dauphiné, there appeared, after the above mentioned treatment with hydro fluoric gas and water, groups of slender, parallel spindle-shaped depressions crowded closely together, or of sharp edged subindividual crystal prisms or little tablets; while the etchings upon the cleavage planes of oligoclase from Ytterby were jagged, rhomboidal depressions and on the cleavage planes of anorthite from Vesuvius were polygonal, facet-like, roundish or net-shaped depressions.

Through the action of hydro-fluosilicic acid the trellis-like surfaces of the thin sections of amazonite were mostly etched in the form of delicate net-like depressions; upon the most perfect cleavage planes of albite from Dauphiné appeared peculiar sharp-edged, wedge-shaped etchings which were inclined to the plane of cleavage at a very sharp angle and were often distinguished by a regular arrangement in parallel rows, (see Plate II, Fig. 1,); and upon the oligoclase feldspar appeared either in slender grooves of diverse forms and variously placed, or lenticular, half moon-shaped, oval and quite rectangular depressions. The groove-like depressions were the more rare the less soda the feldspar contained. Upon the

Fig. 4), and sometimes a small amount to calcium also.

a The mineral specimen consists of pliant leaves or scales; most of the cut-sections show a thick, parallel, rectilinear or undulating grooving; the silicic fluoride crystals formed are small and sparingly distributed (Plate II, Fig. 5, right side..................*Potash mica.

b The mineral specimen is of very perfect cleavage ; most of the cut-sections are distinguished by a *cross-banded* or *trellis structure;* the silicic fluoride crystals are larger and heaped up in quite large numbers along the trellis-like grooves.

Near the silicic fluoride of potassium appear some silicic fluoride crystals of sodium (Plate I, Fig. 16) *Microline.

g The mineral specimen is of very perfect cleavage; most of the longish-banded sections show no grooving, if they are quite homogeneous, but are sometimes composed of two long halves which in polarized light show different colors. The cut-sections, furnished with enclosures of grooved bands, offer, near the silicic fluoride of potassium, more or less silicic fluoride of sodium, at times also a little silicic fluoride of calcium ..................*Orthoclase.

d Fragments perfectly cleavable, or cut sections of glassy appearance and fissured structure. A good deal of silicic fluoride of sodium is almost always found near the silicic fluoride of potassium.....*Sanidine.

e The mineral fragments show no perfect cleavage; the roundish (polygonal) cut sections are always clear or distinguished by beautiful enclosures arranged in the forms of wreaths (Plate II, Fig. 2) .*Leucite.

*g* belong almost exclusively to sodium.

Treated with chlorine gas, the mineral

a is not affected.

Perfectly cleavable fragments, whose surfaces often show etchings after treatment with hydrofluoric acid (Plate II, Fig. 1); usually the cut-sections have parallel rectilinear grooves, and in polarized light give variegated lamellar colors......*Albite (pericline).

b the mineral is strongly affected, and separates gelatinous silica which can be recognized easily by means of fuchsin solution.

aa Granular; quadratic, rectangular, hexagonal, and

Minerals of the second group, when in thin sections, usually offer homogeneously colored sections, sometimes variously shaded in the crystal scales, but among these minerals appear also others, such that, colorless or only faintly colored, (many olivines, dichroites, epidotes, augites, diallages, enstatites), they might be mistaken for minerals of the first group. But since all minerals of this group contain more or less iron (or manganese), their thin sections can, through strong heat with the oxydation flame, be given a yellowish, reddish or brownish homogeneous coloring by which they can readily be distinguished from minerals of the first group.

The kind and intensity of color which comes by heating (of proper strength and continuance) upon the thin sections of minerals of the same species, but from different localities, sometimes determines with sufficient accuracy the relative quantity of iron (or manganese).

*With the appearance of a homogeneous intense color the thin sections of many minerals of the second group acquire the peculiarity of showing a more or less strong dichroism and absorption of light.* Which characteristic, before heating the minerals (so long as they were colorless or only faintly colored), could not be noticed at all, or only in a far less degree.

*This process can be performed in the following way:* Upon a small strip of platinum, slipped into the slit of a wooden handle, lay the thin section specimen of the size of 1½-3 □ $^{mm}$ and subject it, by means of the blow-pipe, to the oxidyzing flame for from 1½ to 3 minutes, so that for this length of time the specimen may be at a red heat; yet it is advisable to interrupt the heating after 1½ minutes and to investigate the specimen microscopically, and, in case it is colored, it should be put to the dichroscopic test; because by a longer continuance of heat many minerals are either colored so dark (gray or grayish-brown) that they lose in great measure their transparency and are no more fit for dichroscopic study, or they are entirely melted.

If the length of heating, which thin section fragments of equal size and under the above mentioned conditions require for fusion, has been determined for certain minerals, as steps in a scale of fusibility, then the melting-point of every other mineral in thin sections can be determined approximately by comparison with these; but one must observe that the contact of a mineral difficult of fusion with one easily fusible, demands heating in the high degree of the former mineral, and especially should this be observed in such minerals as usually hold an easily fused glass cement in rich masses.

*I have made experiments upon the following mineral sections* in regard to the change of color produced by heating and to the possible observation of dichroism, and in regard to their fusibility.

(*a.*) Upon the colorless olivine sections of nepheline pikrite from Devin at Wartenberg, which, after about two minutes of heating, received a homogeneous dark-yellow color, and then showed as strong dichroism as the yellowish-brown amphibole sections of many basalts.

(*b.*) Upon the nearly colorless, very pale-yellow olivine sections from Kozákov at Turnau. These became by heating, in reflected light, grayish-yellow, in places grayish-brown, in transmitted light grayish yellow or grayish-brown (in places darker), and less transparent. Dichroism (dark grayish-yellow or grayish brown and light grayish-white with a streak of blue), and light absorption were distinctly observed.

(*c.*) Upon pale bluish-white almost colorless sections of blue dichroite from Orrijaerfvi in Finnland. These by strong heating acquired only a pale yellowish color, but, while before heating only a slight dichroism could be noticed, it appeared quite strong after the heating, when the changes of greenish-yellow, siskin-green and violet-blue were very beautiful.

(*d.*) Upon pale-bluish sections of blue dichroite from Bodenmais in Bavaria. These became, through heating, dark grayish-blue in reflected light, and in transmitted light dark grayish-brownish-violet and slightly pellucid, in some places opaque. Dichroism showed itself quite strongly thus: grayish-greenish-yellow and pale smalt-blue. Moreover, it was observed that a perfect cleavage appeared.

(*e.*) Upon the almost colorless sections of scapolite from Malsjö in Wermland, which became through heating an ashy-gray in reflected light, with a streak of violet, in transmitted light grayish-blue, in some places a brownish changing streak, and were scarcely translucent. Dichroism was scarcely noticeable either before or after heating.

(*f.*) Upon the grayish-white almost colorless sections of grayish green epidote from Schwartzenstein in Zillerthal (Tirol). These, after some 1½ minutes of heating became grayish-yellow, but yet remaining literally transparent, showed a strong dichroism (change of color; pale bluish-green, emerald-green and pale violet-brown), which was less distinctly observed before heating.

After 2½ minutes of heating the epidote thin sections became grayish-yellowish-brown very slightly pellucid, and after some 3 minutes of heating they became dark grayish-brown, opaque and with a curved distortion due to crumpling.

(*g.*) Upon thin sections of (black) augite from Wartha on the Eger (cut parallel to the pinacoid), colored brownish-gray with a streak of violet. After two minutes of heating the brownish shade on these appeared stronger and a quite distinct dichroism (greenish-yellow and violet-gray), and clear distinctions in the absorption of light were noticed. These, though in a less degree, could be noticed before heating.

(*h.*) Upon the almost colorless very pale-yellow sections of bronzite from Grauthal, which by heating became bright yellow, in the crevices a pale yellowish-brown, and presented a very distinct dichroism (grayish white and light brownish-greenish-yellow), especially upon the darker places.

The thin sections of micaceous rock from Libschitz which consist of biotite, amphibole, a tetragonal mejonite mineral, magnetite, apatite, and in some places rich brown glass-cement, were, after some three minutes of intense heating, changed into greenish glass, full of bubbles and containing colorless roundish bodies thickly crowded together, in which only biotite and amphibole could be distinctly recognized.

2. *Upon the use of cobalt-solution for identification of alumina and magnesia in sections of minerals free from iron (or manganese).*

The known reaction upon alumina and magnesia by heating the specimen treated with cobalt-solution upon coal can be applied to the investigation of the thin sections of colorless minerals free from iron; yet it must be noticed: (*a*) that the thin section specimens must be moistened many times with cobalt-solution and always very strongly heated if even a partially successful result is to be obtained, and (*b*) that thin sections having become dark or opaque by heating with cobalt-solution, can be made again transparent by being boiled with water or with a very dilute nitric acid.

The blue color given to aluminous minerals by heating with cobalt-solution appears stronger in reflected light than in transmitted light, because the action of the reagent mentioned usually reaches to every part of the surface of the thin section of the mineral. And the rougher the surface is so much the more distinct is the desired effect. It seems advisable to expose the mineral thin section, before heating with cobalt solution, to the action of fluohydric gas or of chlorine gas according to the insolubility of the mineral in acids.

I have only made these experiments upon the thin sections of two minerals: quartz-andesite from Sebesvarallya in Hungary[1], which, heated with cobalt-solution and boiled in water, caused the bluish andesine section to be clearly recognized; and amazonite from Miask which was previously treated with fluohydric gas and water. The latter thin section heated with cobalt-solution and boiled in dilute nitric acid, appeared in many places bluishly transparent, yet the blue color was more strongly noticed in reflected light.

## VI. ANALYTICAL GUIDE

### FOR DETERMINATION OF MINERALS[2] APPEARING IN CRYSTALLINE ROCKS, BY THE NEW CHEMICO-MICROSCOPIC METHOD.

**1. The specimen is a broken fragment, cleavage lamina or thin polished section of a homogeneous mineral.**

*If the specimen is a broken fragment or a cleavage lamina* of a homogeneous mineral, take a piece the size of a barleycorn, crumble it into many little particles, lay these in the midst of a balsam layer spread upon an object-glass and made resinous by heating, cover the particles with a drop of 3 per cent. strong hydrofluosilicic acid of the size of a pea, observe whether a bubbling[3] occurs or not, and leave the object-glass, for the specimen to dry, in a place perfectly protected from dust. (In not too moist air the drying will require from six to twelve hours). Then subject the entire dried portion of the object and the upper surface of the somewhat smooth cleavage fragment to close microscopic examination magnified from 200 to 600 diameters.

It is to be noted that a satisfactory result can be obtained with the smallest grain of the specimen, although the drop of hydrofluosilicic acid must be correspondingly lessened in size

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[1] Received by kindness of Prof. G. Von Rath.

[2] Since not all the minerals appearing in crystalline mixed rocks offered satisfactory results in these experiments this analytical guide is useful only for such minerals as have been actually investigated in their individual characteristics, or which allowed their characteristic reactions to be developed with the greatest probability, according to their nature and the laws involved.

[3] Development of a colorless, odorless gas.

*If the specimen is a thin polished fragment* which measures about 2–4 $\square^{\mathrm{mm}}$, then heat the object-glass gradually and press the specimen carefully upon it with the point of a penknife, so that it will cling firmly and no little bubbles remain between it and the object-glass, and then continue exactly as indicated in the foregoing.

The remark may be permitted here that the smallest homogeneous portion of a thin section of a mineral treated with hydrofluosilicic acid must give perfectly reliable results.

NOTE.—*The minerals named below marked with an asterisk have already been investigated with hydrofluosilicic acid.*

A) The specimen is in the form of the finest splinters or the thinnest (more or less) transparent cut section.

*On treating the specimen with hydrofluosilicic acid*

A′ A continuous bubbling is noticed.
The silicic fluorides formed
*a* belong almost exclusively to calcium (Plate I, Fig. 6.)
The cleavage crevices of the specimen show
a a rhombohedral mineral...............*Calcite.
b a rhomboidal mineral................Aragonite.
*b* belong almost exclusively to magnesium (Plate I, Fig. 12.)
(The cleavage crevices of the specimen show a rhombohedral mineral)........................*Magnesite.
*c* belong in great part to calcium as well as magnesium.
The cleavage fissures of the specimen show a rhombohedral mineral.........................*Dolomite.

B′ No bubbling is noticed.
The silicic fluorides formed
*d* belong for the most part to lithium, in a small degree to potassium or even to sodium.
Scaly, colorless or light colored (from Roznau, peach-red) particles; for the most part thick, parallel grooved sections.... ............................*Lithia mica.
*e* belong for the most part to lithium and iron[1] (Plate II, Fig. 5, left side), in a small degree, sometimes to potassium.
Scaly, light-colored particles and little leaves, for the most part thick, parallel-grooved sections. *Lithia-iron mica.
*f* belong for the most part to potassium (Plate I, Figs. 1 and 2), often in a lesser degree to sodium (Plate I,

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[1] The iron fluoride crystals are colored dark yellow by the action of chlorine gas.

onal and trigonal, cut sections usually distinguished by a blackish-blue or reddish, close trellis-work. Hauyne.

*l* belong to calcium and sodium, in all probability of almost equal parts, but the greater part to calcium and the lesser, though not essentially different, to sodium.

The silica separated by chlorine gas is

a not gelatinous.

Fragments colorless or light-colored, and with perfect cleavage, often with delicate and close parallel groovings; the cut-sections for the most part striated with parallel, delicate, close grooves, and in polarized light displaying parti-colored lamellar structure. (Plate I, Fig. 19)....................*Labradorite.

b gelatinous.

Physical properties same as under *k*, b..Some hauyne.

*m* belong for the most part to calcium, in a much smaller degree to sodium, sometimes also a small quantity to magnesium and iron.

The silica separated by chlorine gas is

a not gelatinous. The specimen is strongly affected.

Fragments colorless or light colored, with perfect cleavage; for the most part the cut-sections are banded with parallel grooving, and show in polarized light a parti-colored lamellar structure. (Plate I, Fig. 20)......................Some *anorthite.

b gelatinous, The specimen is strongly affected.

Most of the tetragonal and rectangular cut-sections are colorless, yellowish or brownish; the colorless ones are colored yellow by red heat, at least around the edges and in the crevices. ............*Melilite.

*n* belong almost exclusively to calcium (in a much smaller quantity to sodium, magnesium, iron and manganese.)

By action of chlorine gas the specimen

a is very slightly affected.

aa Blackish, sharp-angled grains, mostly with a grayish-white translucency and a sub-metallic lustre, which give a titanium reaction or cut-sections of tesseral crystals of a grayish-white (yellowish or brownish) color and dark angles......Perofskite.

bb Reddish, brownish, blackish brown-to-black grains which give no titanium reaction; reddish or brownishcut-sections of tesseral crystals..Some garnets.

b Quite strongly affected, yet *without* the separation of *gelatinous* silica.

aa Tetragonal prisms or columnar particles; cut sections grayish-white; rectangular and tetragonal, and parallel-barred or fibrous, showing characteristic etchings after treatment with chlorine gas. (Plate II, Fig. 4)....................*Scapolite.

bb Hexagonal prisms; cut-sections rectangular and hexagonal, colorless or furnished with rows of powder-grains, which after treatment with chloine gas, or with hydrofluosilicic acid, show characteristic subindividual crystals (etchings). (Plate II, Figs. 16–20).......................*Apatite.

gg Yellowish, greenish or brownish, short monoclinic tablets or prisms which give the titanium reaction; cut-sections pale yellowish, greenish or brownish-gray (usually spindle-shaped) of monoclinic forms *Titanite.

dd Colorless or light colored fragments with perfect cleavage, often with parallel grooves; cut-sections for the most part with parallel rectilinear groovings, and showing in polarized light a variegated lamellar structure..............Some *anorthite.

g Quite strongly affected and *with* the separation of *gelatinous* silica.

aa Tetragonal prisms or columnar fragments; grayish-white or pale yellowish or greenish tetragonal and rectangular cut-sections or parallel-striped or fibrous particles.......................*Mejonite.
Here also might belong some...........Melilite.

bb Fragments of colorless or white monoclinic crystals or bar-like to fibrous aggregates..*Wallastonite.

*o* belong almost exclusively to magnesium (the silicic fluorides are *not colored* by chlorine gas, or are only colored slightly an orange yellow).

a Grains, with little evident cleavage, very hard; cut-sections mostly rectangular or irregular, roundish, which after red heat show a marked dichroism (Plate II, Fig. 10)...........................*Dichroite.

b Pliant, very soft and flexible leaves, scales or groups of scales, white or pale colored; cut-sections mostly striped..................................*Talk.

g Grains with perfect cleavage, hard, pale-greenish or onal and trigonal, cut sections usually distinguished by a blackish-blue or reddish, close trellis-work. Hauyne.

*l* belong to calcium and sodium, in all probability of almost equal parts, but the greater part to calcium and the lesser, though not essentially different, to sodium.

The silica separated by chlorine gas is

a not gelatinous.

Fragments colorless or light-colored, and with perfect cleavage, often with delicate and close parallel groovings; the cut-sections for the most part striated with parallel, delicate, close grooves, and in polarized light displaying parti-colored lamellar structure. (Plate I, Fig. 19)....................*Labradorite.

b gelatinous.

Physical properties same as under *k*, b..Some hauyne.

*m* belong for the most part to calcium, in a much smaller degree to sodium, sometimes also a small quantity to magnesium and iron.

The silica separated by chlorine gas is

a not gelatinous. The specimen is strongly affected.

Fragments colorless or light colored, with perfect cleavage; for the most part the cut-sections are banded with parallel grooving, and show in polarized light a parti-colored lamellar structure. (Plate I, Fig. 20).......................Some *anorthite.

b gelatinous, The specimen is strongly affected.

Most of the tetragonal and rectangular cut-sections are colorless, yellowish or brownish; the colorless ones are colored yellow by red heat, at least around the edges and in the crevices. .............*Melilite.

*n* belong almost exclusively to calcium (in a much smaller quantity to sodium, magnesium, iron and manganese.)

By action of chlorine gas the specimen

a is very slightly affected.

aa Blackish, sharp-angled grains, mostly with a grayish-white translucency and a sub-metallic lustre, which give a titanium reaction or cut-sections of tesseral crystals of a grayish-white (yellowish or brownish) color and dark angles.......Perofskite.

bb Reddish, brownish, blackish brown-to-black grains which give no titanium reaction; reddish or brownishcut-sections of tesseral crystals..Some garnets.

b Quite strongly affected, yet *without* the separation of *gelatinous* silica.

aa Tetragonal prisms or columnar particles; cut sections grayish-white; rectangular and tetragonal, and parallel-barred or fibrous, showing characteristic etchings after treatment with chlorine gas. (Plate II, Fig. 4)....................*Scapolite.

bb Hexagonal prisms; cut-sections rectangular and hexagonal, colorless or furnished with rows of powder-grains, which after treatment with chloine gas, or with hydrofluosilicic acid, show characteristic subindividual crystals (etchings). (Plate II, Figs. 16–20).......................*Apatite.

gg Yellowish, greenish or brownish, short monoclinic tablets or prisms which give the titanium reaction; cut-sections pale yellowish, greenish or brownish-gray (usually spindle-shaped) of monoclinic forms *Titanite.

dd Colorless or light colored fragments with perfect cleavage, often with parallel grooves; cut-sections for the most part with parallel rectilinear groovings, and showing in polarized light a variegated lamellar structure.............Some *anorthite.

g Quite strongly affected and *with* the separation of *gelatinous* silica.

aa Tetragonal prisms or columnar fragments; grayish-white or pale yellowish or greenish tetragonal and rectangular cut-sections or parallel-striped or fibrous particles .......................*Mejonite.
Here also might belong some...........Melilite.

bb Fragments of colorless or white monoclinic crystals or bar-like to fibrous aggregates..*Wallastonite.

*o* belong almost exclusively to magnesium (the silicic fluorides are *not colored* by chlorine gas, or are only colored slightly an orange yellow).

a Grains, with little evident cleavage, very hard; cut-sections mostly rectangular or irregular, roundish, which after red heat show a marked dichroism (Plate II, Fig. 10)..........................*Dichroite.

b Pliant, very soft and flexible leaves, scales or groups of scales, white or pale colored; cut-sections mostly striped.................................*Talk.

g Grains with perfect cleavage, hard, pale-greenish or yellow; cut-sections with parallel rectilinear grooving..............................Some enstatite.

*p* belong to magnesia, iron and potassium.

Short, dark-colored prisms with evident cleavage on the basal planes and hexagonal leaves (Plate II, Fig. 6). Some *biotite.

*q* belong to magnesium and iron, sometimes also in a slight degree to calcium (the silicic fluoride crystals belonging to iron are colored orange yellow by chlorine gas and are blackened by sulphide of ammonium gas.

The silica separated by chlorine gas is

a gelatinous.

Cut-sections colorless, yellowish, greenish, brownish, showing dichroism after red heat, clear or marked with non-rectilinear cleavage crevices. These sections after treatment with hydrofluosilicic acid show often subindividual crystals (etchings) (Plate II, Figs. 11 and 12)..........................*Olivine.

b not gelatinous; sometimes the specimen is not at all affected.

aa *Hard* grains, which present *no, or only an imperfect cleavage*; cut-sections show *tesseral* crystals upon which an imperfect cleavage, or none at all, is to be observed.

△ Grains blood-red or dark brown; cut-sections dark red and brownish....*Pyrope and some garnets.

△△ Grains dark green, blackish-brown and blackish; cut sections greenish, grayish or brownish...... *Pleonast (picotite).

bb Greenish hexagonal tablets, of *very perfect cleavage*, soft, pliant scales, or leafy or scaly grooves; cut-sections greenish with parallel groovings or stripes, or delicate scaly spangles .....*Chlorite.

gg Grains with rather perfect or *perfect cleavage*, quite hard, greenish, blackish green or greenish-black; cut-sections grayish-white, light or dark green, with very close parallel, rectilinear or columnar groovings, or fibrous.

The silicic fluoride crystals are colored orange yellow by chlorine gas.

△ in a small part only................Enstatite.

△△ in a greater part (Plate II, Fig. 9)*Bronzite.

△△△ in the greatest part............*Hypersthene

*r* belong to calcium, magnesium and iron, or calcium and iron.

Delicate cleavage fragments or cut-sections show

aa either before or after heating a very strong dichroism. The silica separated from the heated specimen by chlorine gas.

△ is gelatinous.

Very perfectly cleavable, hard, usually grayish-green, monoclinic crystals, or barred or granular aggregates; cut-sections grayish or greenish-white, with rectilinerally parallel but very light and delicate groovings..............*Epidote.

△△ not gelatinous.

Black or blackish-green, monoclinic, columnar crystals of various lengths; cut-sections greenish, grayish, yellowish or brownish, upon which quite perfect cleavage crevices are usually seen. (Plate II, Fig. 7). These intersect in regular diagonal sections at an angle of 124°30′*Amphibole.

bb none or only slight dichroism.

△ Crystals greenish-black, black, or blackish-brown, monoclinic, short columnar; greenish, yellowish, brownish or grayish cut-sections whose cleavage crevices are often quite rectilinear. They intersect in regular diagonal sections at an angle of 87°6′.. *Augite (pyroxene).

△△ Grains thick, plate-like, dark-gray, brownish or blackish, perfectly cleavable in one direction, and striped on the most perfect cleavage surfaces, or fibrous; cut-sections with parallel and sharply rectilinear but light groovings in one or two directions (Plate II, Fig. 8)......*Diallage.

*s* The silicic fluorides are lacking entirely or appear only very rarely.

a Cut-sections pale or colorless; changed by hydrofluoric gas effervesce in sulphuric acid..Pure alumina silicate. like *chiastolite (Plate II, Fig. 13), disthene, andalusite. etc., which may sometimes be distinguished by etchings.

b Dark red hexagons or irregular particles, or scales with tattered edges (in cut sections)......Hematite.

g Brown or yellow-brown, mostly earthy particles (in thin sections)........................Limonite.

B) The specimen is in the most fragile splinters or the thinnest cut-sections.
- A′ Black, opaque.
  - a Is distorted by heating (sometimes leaving a red portion behind it). This is
    - aa Amorphous.............................Anthracite, coal.
    - bb scaly...........................Graphite,
  - b Is not changed by treating, or only colored brownish or reddish at the edge..............Magnetite.
- B′ Blackish-brown, slightly translucent.
  - a A rhombohedral cleavage disclosed by the cleavage crevices, and, heated with a drop of sulphuric acid, colors the latter blue at the edge (according to Sandberger).....................Titanic iron.
  - b Is tesseral and gives chrome reaction..Chromite.

**2. The specimen is a fragment or a portion of a thin-section of a crystalline rock.**

*If the specimen is a crystalline rock* out of which the individual mineral to be investigated can be selected, in the form of very tiny but perfectly homogeneous particles, by help of strong magnifying glass; or if it is a thin section out of whose sections the smallest homogeneous particles can be cut; in either of these cases, the separate investigation of each mineral, for the proof of its real nature, should be undertaken as the surest way; but the fulfillment of all the conditions for an infallible result (namely, purity of the hydrofluosilicic acid used, as well as of the Canada balsam, and protection from dust) is to be the more carefully observed the smaller the specimen to be studied.

If the above mentioned specimen, in the form of a thin section, consists only of minerals each of which contains other metals (or one other metal) a separation and separate investigation of the individual minerals is not usually necessary, but the general treatment of it with hydrofluosilicic acid usually leads to perfectly satisfactory results. For example, if the specimen is a variety of basalt, which consists of augite or amphibole, magnetite and nepheline, or of augite and amphibole, magnetite and glass substance, (magma) and it be treated with hydrofluosilicic acid, there appear, constantly, in the first case, besides the silicicfluorides of calcium, magnesium and iron (arising from the augitic ingredient), silicicfluoride crystals of sodium, sometimes also, in less quantity, those of potassium, while in the latter case, the more or less rich appearance, or sometimes entire lack of silicicfluorides of the alkalies (and the insolubility in chlorine gas), sufficiently characterize the chemical nature of the glass substance (magma). If the specimen is a variety of porphyry which contains besides quartz and monoclinic feldspar, only one triclinic feldspar, and it is treated with hydrofluosilicic acid, a tolerably certain conclusion can be drawn concerning the chemical nature of the triclinic feldspar from the quantitative proportions of the silicic fluoride crystals of calcium and sodium.

These cases in which a common treatment of several minerals with hydrofluosilicic acid allows the chemical nature of the minerals to be recognized, often present themselves to the microscopical petrographer in investigating thin sections of rocks; but far more frequently the preparation of such cases lies in the hand of the investigator.

In the thin sections of most rocks particles appear in some places which allow a general treatment with hydrofluosilicic acid for the proof of the chemical combinations of their mineral mixed portions. And such particles however small they may be can be cut out of the thin sections and investigated.

If the thin section specimen of a crystalline rock, in whose minerals occur one and the same or several similar metallic elements, be treated with hydrofluo-silicic acid, the totality of silicic fluoride crystals formed affords in all cases the analogy of a partial chemical Bausch-analysis.

But in most cases more is aimed at in treating the specimen with hydrofluo-silicic acid than that a Bausch-analysis may be afforded the petrographer, since by certain precautionary measures—especially if the hydrofluo-silicic acid drop has spread only a very little over the edge of the thin section and if it is dried in a perfectly horizontal position on the object-glass and in perfect quiet,—the silicic fluoride crystals formed do not mingle regardless of order, but for the most part are formed on the upper surface of that mineral to which they belong. In such cases characteristic forms of partial chemical analyses of the individual minerals have been obtained.

## VII. REMARKS UPON THE IMPORTANCE OF THE EXPLAINED METHODS FOR DETERMINATIVE MINERALOGY AND ANALYTICAL CHEMISTRY.

Upon the basis of many analytical experiments which I have made according to the above methods upon many and various (about one hundred) minerals, I believe I may be allowed to express the hope that my elements of a new method for the chemico-microscopic analysis of rocks and minerals may offer many suggestions not unimportant to the petrologist and mineralogist, and also in some measure to the analytical chemist, and that they are worthy of a continued and broader development (by means of other valuable agents).[1]

Without mentioning the amount of time and many requisites —a favorable place for work, the necessary apparatus, and numerous reagents—which the chemico-analytical experiments undertaken upon minerals in the usual way demand, the mineralogist as well as the petrographer is obliged to experiment upon one or a few grains of the specimen, and, after one or more failures or experiments producing only negative results, must discontinue his attempts on account of lack of material. And in such a case the best chemist cannot aid him unless the spectroscope can offer assistance.

On the other hand, our "universal method" (and at times also the methods based upon the application of fluohydric gas) applied to the smallest specimen, offers a safe analysis of the metallic elements, whether they appear free or in monoxides, or in their manifold salts, in hyperoxides or their analagous sulphur, selenium, tellurium, arsenic and antimony compounds; which, with the coöperation of the physical properties, usually suffices for the determination of the mineral species. Moreover our method requires no special locality for the work, no large number of implements and reagents, but—besides Canada balsam, object-glasses and a spirit lamp—only a caoutchouc flask filled with perfectly pure hydrofluo-silicic acid of 3 per cent. strength, and a caoutchouc stick kept in a caoutchouc tube. And the whole time required for investigating a mineral —without counting the time required for drying the drop of acid—is in most cases only from five to ten minutes.

Although I have already examined more than a hundred mineral species by means of hydrofluo-silicic acid, still I consider this only a small fraction of the work yet to be completed in order to be able to publish a practical and perfectly reliable key for the determination of all minerals according to the above described methods. But I hope in a few months to reach the desired end. I will here confine myself to a few hasty remarks which indicate the foundations for the projected key for the determination of mineral substances, and which will contain the requisite directions for many cases.

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[1] Preeminently do experiments with acids analogous to hydrofluosilicic acid, especially with borfluoric and hydrofluotitanic acid, promise favorable results.

(*a.*) The silicic fluorides known up to this time—besides those appearing in petrologically important minerals, and specified on pages 17 to 23—are the following:

*The silicic fluoride of ammonium* (plate I, fig. 1, s, t,) ($[NH_4]_2 Si F_6$) must be dimorphous (Marignac, Ann. chem. phys.,[3] *LX*—301 and Jahresb. über Fortschr. d. Chem. 1860 [pro 1859], page 107, and 1861 [pro. 1860], page 98). From the pure solution it crystallizes according to Marignac in tesseral combinations of octahedrons with hexahedrons; from solutions, on the other hand, which are rich in hydro-fluoric gas or fluoride of ammonium, in combinations of the hexagonal system: $\infty P. P. 0P.$ $\infty P. P. 2P. 0P.$ According to Marignac's report $P: P. = 139° 36'$, $2P: 2P = 127° 25'$, $0P: P = 136° 20'$, $0P: 2P = 117° 39'$. Through re-crystallization the hexagonal crystals become tesseral.

From the solutions diluted with surplus fluoride of ammonium, the silicic fluoride of ammonium crystalizes in double-folded, quadratic combination forms ($\infty P. 0P$, rarely $\infty P \infty$), which many times appear cube-shaped (Jahresb. über Fortschr. d. Chem., 1860 [pro. 1859], page 107).

I obtained the silicic fluorides of ammonium (with a surplus of hydrofluo silicic acid), always in large sharp-edged tesseral forms ($\infty 0 \infty . 0$), which could not be distinguished from the silicic fluorides of potassium, unless it is permissible to designate the unusually beautiful scale-structure and the step-like nature of the surfaces observed on the imperfectly formed crystals of silicic fluoride of ammonium as special marks of difference.

Since the ammonium salts are, by their volatility when heated, to be distinguished easily and separated from the potassic salts, the isomorphism of their silicic fluorides is not destroyed by the investigation of the mineral substances. If, for example, a thin particle is to be tested for potassium, the specimen is heated before treatment with hydrofluo-silicic acid or with fluohydric-gas.

*The silicic fluoride of silver* ($Ag_2\ Si\ F_6+4\ H_2O$) crystallizes in quite flat pyramids of the tetragonal system, which are liable to deliquesce in the air. (Marignac, Comptes rendus XLVI—854 and Jahresb. über Fortschr. d. Chemie v. Kopp u. Will, 1859 [für 1858], pag. 145, and 1860 [f. 1859], pag. 107).

*The silicic difluoride of mercury* ($Hg_2\ Si\ F_6+2H_2\ O$) prepared by the solution of carbonic oxide of mercury in fluosilicic acid and evaporation of the solution, appears in very transparent prismatic crystals.

*The silicic fluoride of mercury* ($Hg\ Si\ F_6+6H_2\ O$) crystallizes in water-clear rhombohedrons, arranged like stairs, and liable to deliquesce on exposure to air, and these are formed when the solution of quicksilver oxide in hydrosilicic acid is so concentrated that the crystals of the above-mentioned compound begin to separate, and also when the solution is left to itself at a temperature not exceeding 15°. (Gmelin's Handb. d. Chemie, pag. 865).

*The silicic fluoride of lead*: ($Pb\ Si\ F_6+4H_2\ O$) crystallizes according to Marignac, (Ann. Min. [5] XV, 221 u. Jahresb. über Fortschr. de Chemie, 1860, pag. 107), in forms of the monoclinic system, and especially in the combinations: 0*P*. ∞ *P*, 0*P*. ∞ *P*. ∞*P*2. Ᵽ∞ .—*P*. *P*. 2*P*∞ . In the clinodiagonal chief section ∞ *P*:∞ *P* =64° 46′, ∞*P*2: ∞*P*2=103° 30′, *P* : *P*=100° 2′,—*P*:—*P*=101° 23′, 0*P*: ∞Ᵽ ∞=91° 30′, 0*P*:*P*=130° 29′, 0*P*:—*P*=131° 24′, and 0*P*: 2*P*∞=128° 6′. The crystals are easily cleavable parallel to 0*P* and less easily parallel to ∞Ᵽ ∞.

*The silicic fluoride of lead* $Pb\ Si\ F_6+2H_2\ O$ is, according to Marignac (as above), in some cases monoclinic, and usually appears in the form ∞ *P*. 0*P*, rarely with ∞ *P*∞ or *P*∞ . In the clinodiagonal chief section ∞ *P*: ∞ P=71° 48′, 0*P*: ∞ *P*∞ = 103° 44′, 0*P*: ∞ *P*=90°, 0*P*: *P*∞ = 127° 55′.

The large, beautiful, sharp-edged and smooth-faced crystals of *silicicfluoride of lead* (magnified to the 400th power) which I obtained from the lead-glance from Pribram, by means of hydrofluosilicic acid, had the forms: ∞ *P*.0*P*, ∞ *P*. 0*P*. ∞ Ᵽ∞ ,∞ *P*. ∞Ᵽ∞ *mP*. *m*Ᵽ∞ . The prisms and needles were in radial groups and bore a great similarity to the aggregate forms of silicicfluorides of calcium and strontium.

Treated with tolerably dilute sulphuric acid, they were changed into little secondary forms in a confused mass of delicate needles (anglesite?) and were soon colored grayish by hydro sulphuric gas.

*The silicicfluoride of copper* ($Cu\ Si\ F_6+6H_2O$) crystallizes according to Marignac (Ann. Min. [5] XV—221) in forms of the hemihedral hexagonal system, usually in the combination forms $\infty P2.\ R;\ R{:}\ R = 125° 30'$. If the silicicfluoride of copper crystallizes at 50° T, it appears as $Cu\ Si\ F_6+4\,H_2O$ in forms of the monoclinic system.

The rare, almost colorless crystals of silicic fluoride of copper, formed from chalkosine, bornite and tetrahedrite by hydrofluosilicic acid *being greenish-blue* or *bluish-green in reflected light* were usually imperfectly formed and always *deliquesced on the edges and corners.* After treatment with chlorine gas they appeared bluish-green in transmitted light.

*The silicic fluoride of nickel* ($Ni\ Si\ F_6 + 6\ H_2\ O$) formed by dissolving $Ni\ CO_3$ in $H_2\ Si\ F_6$, crystallizes according to Marignac (Ann. Min. [5] XV—262; Jahresb. über Fortschr. der Chemie v. Kopp u. Will, 1860, page 103, and Gmelin's Handb. d. Ch. p. 571) in forms of the hemihedral hexagonal system, and in greenish rhombohedrons and hexagonal prisms; is easily soluble in water. R: R=127° 34′,—2R:—2R=97° 10′, R:∞ R =116° 13′, ∞ R: —2R=131° 23′, 0R: R=149° 14′, 0R:—2R= 130° 0′. Specific gravity=2.109 (Topsoë).

The crystals of silicic fluoride of nickel formed from ullmanite and carbonate of nickel were, magnified to the 400th power, quite large, either prism-shaped, needle-shaped or similar to a rhombohedron combined with the basal face, very sharp-edged and smooth-faced, almost colorless in transmitted light, *grayish green in reflected light,* and usually covered with a dark-gray granular substance which is greenish-yellow and delicately granular in reflected light.

By the action of chlorine gas they acquired a more or less greenish, in some places emerald green color, and treated with dilute sulphuric acid were changed into small secondary forms in a close network of delicate, long, grayish needles; in reflected light this network appeared light grayish-bluish-green.

*The silicic fluoride of cobalt* ($Co\ Si\ F_6+6H_2\ O$), formed by dissolving carbonate of cobalt in fluosilicic acid appeared (according to Berzelius) in pale-red rhombohedrons and six-sided prisms which are easily soluble in water. According to Grailich (Kryst. opt. Unters. Wiens; u. Olmütz, 1858, 75), R: R (Polk.) = 126° 59′, R: ∞P2=116° 30′. The crystals are indistinctly cleavable parallel to ∞ P2. The specific gravity=2.067 (Topsoë) (Gmelin's Handbuch der Chemie, page 516).

The silicic fluoride of cobalt formed from cobaltine by means of hydrofluosilicic acid, appeared (magnified to the 400th power) in large, sharp-edged, smooth-faced crystals, which seemed to be isomorphous with the silicic fluoride crystals of nickel and iron. While the small crystals were almost colorless the larger presented a distinct, pure bluish or pale-violet color.

By action of chlorine gas the silicic fluoride crytals of cobalt were colored for the most part pale violet-brown, and dissolved largely into a violet-red liquid. Treated with rather dilute sulphuric acid, they gradually lost their bluish color, became colored pale rose-red, and about the borders merged into delicate grains.

*The silicic fluoride of cadmium* ($Cd\ Si\ F_6 + 6H_2\ O$) crystallizes, according to Marignac, (Compt. rend. *XLVI*—854, and Jahresb. ü. Fortschr. d.Chemie. 1859 [145] and 1860 [107]), in long prism-shaped, transparent forms of the hemihedral hexagonal system, which are very easily soluble in water.

*The silicic fluoride of zinc* ($Zn\ Si\ F_6 + 6H_2\ O$) crystallizes, according to Marignac (Ann. Min. [5] XV, 221 and Jahresber. über Fortschr. der Chemie. v. Kopp und Will, 1860, page 108), in hemihedral hexagonal forms, usually in the combination forms $\infty P2.\ R$ or $\infty P2.\ R.\ 0R$ and parallel to $\infty P2$ is distinctly cleavable. $R: R = 127^\circ\ 16'$. Specific gravity=2.104. Easily soluble in water.

Treated with rather dilute sulphuric acid, the crystals of silicic fluoride of zinc, which I obtained from sulphuret of zinc by means of hydrofluosilicic acid were very slowly changed.

*The silicic fluoride of tin* appeared in long prisms, which are very soluble in water, and by evaporation separate into oxide and silica. (Gmelin's Handbook of Chemistry, p. 153.)

*The silicic fluoride of molybdenum*, obtained from molybdenite by means of hydrofluosilicic acid, appears (mag. to the 400th degree) in large sharp-edged, smooth-faced colorless crystals which show greatest similarity to the combination forms of $R.\ 0R$ and $R.\ \infty P\ 2$. And the delicate leaves of molybdenite became transparent and of a beautiful grayish-blue color after treatment with hydrofluosilicic acid.

*The silicic fluoride of platinum* resembles a yellowish-brown gum. (Gmelin's Handbook of Chemistry, p. 1186).

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From the foregoing it is evident that the silicic fluorides of copper, cobalt, zinc, nickel and manganese are isomorphous (for the terminal edges of their fundamental rhombohedrons give the following values: 125° 30′, 126° 59′, 127° 16′, 127° 34′ and 128° 20′), and they appear, with the exception of silicic fluoride of copper, in very similar combination forms (mostly ∞ P2. R and R. 0R). And since these silicic fluorides are also related to those of iron, cadmium, magnesium and possibly several other metals, the series of those metals which appear in such silicic fluoride crystals as can hardly be distinguished by their same types is quite large.

But, since it is possible to separate successfully from each other the isomorphous silicic fluorides of calcium and strontium, and those of iron, manganese and of magnesia, in a very simple way, it is to be hoped that a simple and suitable reaction for all the silicic fluorides of metals of the hemihedral, hexagonal crystal series can be found.

Of the few and quickly made observations and experiments which I made with this end in view, I will mention the following: (*a*) All the specified, hemihedral hexagonal silicic fluorides were almost colorless in transmitted light if they appeared in small quantities, but, on the other hand, when they were brought forth in greater quantities or in larger crystals (from minerals easily decomposed by fluosilicic acid) a distinct, pale-violet-blue or violet-red color appeared upon the silicic fluoride crystals of cobalt; upon those of nickel, a gray color with a faint tint of brown; upon those of copper, a gray with a strong shade of bluish-green, while upon the silicic fluoride crystals of the other metals, except a grayish tint, no color was observed.

(*b*) In reflected light, of the crystals of the silicic fluoride metals mentioned under (*a*), those of copper appeared bluish-green, of nickel, greenish-gray, of cobalt, bluish-gray.

(*g*) By the action of chlorine gas were the silicic fluoride crystals of copper colored bluish green, those of nickel, emerald-green or dark-grayish-green, those of cobalt, violet-brown and those of iron, orange-yellow, but in the presence of cobalt and nickel, citron-yellow or greenish-yellow. The silicic fluoride crystals of manganese contained a faint shading of rose-red, while those of zinc and magnesia remained colorless or became grayish-white.

(*d*) By sulphuric acid the silicic fluorides of most metals were gradually dissolved, though the silicic fluoride of cobalt [illegible] a violet-red liquid. Lastly, hydrosulphuric acid and sulphide of ammonim gas were used; but the results were not so significant that a repetition of the experiment seemed necessary.

Since the silicic fluoride of lead appeared in monoclinic and the silicic fluoride of silver in tetragonal crystal forms, the distinction of the silicic fluorides of the two metals from each other and from the hemihedral hexagonal silicic fluorides of the above named metals, according to the form type, is possible. Moreover the silicic fluoride of lead shows itself in such a way that when treated with tolerably dilute sulphuric acid it is changed into little secondary forms in a net-work of delicate needles (anglesite?).

(b) By the treatment of minerals with hydrofluosilicic acid and by the observation and finally the further separation of the silicic fluoride crystals formed, the knowledge of the electro-positive elements of minerals is gained; therefore for determinative mineralogy (in general) a classification of the mineral kingdom—which is analogous to the classifications explained for petrologically important minerals—in groups according to the electro-positive elements, appears to be worthy of consideration.

(c) There are only a few minerals, which—like baryta, celestine and quartz—are not at all affected by the three per cent solution of hydrofluo-silicic acid; on the other hand some minerals are decomposed by it, which would hardly have been expected; as for example tourmaline, spinel in thin sections, sphalerite, and pyrite in fragments.

(d) The sesquioxides of aluminum, of iron, and as it appears of other minerals also, are quite changed into silicic fluorides by fluosilicic acid; but these *do not* appear to show themselves altogether in crystal forms. This permits the mineralogist as well as the chemist to distinguish the smallest quantity of any oxide, (for example, of iron which is easily changed into silicic fluoride crystals which remain stable in the air) in any (iron) salt, whether soluble or insoluble in acids.

(e) The quantity of silicic fluoride crystals formed under similar conditions and of the silica separated from silicates, offers an excellent means for judging the insolubility of the determined minerals in hydrofluo-silicic acid, and of estimating the importance of the determinations.

*The reactions mentioned under (a) and in connection with the physical properties of the specimens should in most cases suffice for the determination of minerals.*

(f) If the specimen is a simple salt soluble in water, the crystal form of the original salt, or that changed only by the percentage water of crystallization which it has absorbed, can, after the treatment with hydrofluo-silicic acid and drying of the specimen, be brought to appear in conjunction with the silicic fluoride crystals of the electro-positive elements. Thus, for example, if one should treat the larger grains of sodium chloride, Chile saltpeter, glauber salt, borax, etc., with hydrofluosilicic acid (each specimen separately), he will obtain near the hexagonal silicic-fluoride crystals of sodium (appearing in each specimen), in the first specimen little cubes of chloride of sodium, in the second rhombohedrons of sodium nitrate, in the third monoclinic needles of glauber salt, and in the fourth borax crystals recognizable through their form types. If kieserite be treated with hydrofluo-silicic acid, one obtains near the silicic-fluoride crystals of magnesium, epsomite also.

(g) If the specimen is a compound salt soluble in water; there appears near the silicic fluoride crystals of the individual metals, single salts of mineral specimens in their original crystal forms, or in these changed only by the absorption of the water of crystallization. Thus, for example, after the treatment of polyhalite with hydrofluo-silicic acid, I have also noticed at the first glance striated groups of beautiful gypsum crystals near the silicic fluoride crystals of potassium, magnesium and calcium.

(h) If the mineral specimen is a carbonate, on its treatment with hydrofluo-silicic acid, a very strong effervescence is in most cases to be noticed, by which the electro-negative elements, especially the colorless and odorless carbonic acid gas are sufficiently identified.

A more or less strong ebullition was observed, on treatment with hydrofluoric acid, of potash, soda, calcite, magnesite, dolomite, dialogite, witherite, strontianite, cerussite and azurite; on the other hand no development of gas could be noticed in the case of siderite, mesitine and smithsonite, although after the drying of the hydrofluosilicic acid drop, the formation of silicic fluoride crystals followed (less richly) from the carbonate last mentioned.

*In the cases explained under* (f), (g) *and* (h), *our methods offer a perfect chemical analysis of the mineral substance.*

(i) All minerals of the classes of glance, pyrite, and blende (and from the metals of pure silver) which I have heretofore investigated with fluosilicic acid, were more or less strongly affected and gave a corresponding quantity of silicic fluoride crystals. The most beautiful and the largest crystals were obtained from iron, cobalt, nickel and lead minerals, the rarest from minerals containing copper, (chalcosine bornite, tetrahedrite). Pyrite fragments, however, form an exception since they gave only a few small silicic fluoride crystals of iron.

(k) If the material to be examined is in considerable quantity and one wishes to test the electro-negative element also, for a perfect mineral analysis, this can be done with the ordinary reagents, either upon a watch-glass (for the proof of $Cl$, $Br$, $I$, $SO_3$, $P_2O_5$, $B_2O_3$), or in a glass tube (for proof of $F$, $S$, $Se$, $Te$), or upon coal (for proof of $N_2O_5$, $As_2O_3$. $Sb_2O_5$, $As$, $Sb$), or in a salt of phosphorus lead (for proof of $SiO_2$. $TiO_2$, $MoO_3$, $WO_3$).

(l) If this be done to prove the alkalies only (even if they appear in the smallest quantity), in a silicate (for example amphibole, wollastonite), or to establish their absence, then treat the silicate specimen (in little grains) with hydrofluoric gas. Extract the silicic fluorides of the alkalies by gradually boiling in water upon a platinum cover and place this decoction reduced at a moderate temperature to one drop upon the hard plate (of Canada balsam) of an object-glass.

It is to be noticed here that in many cases the silicic fluorides of other metals contained in the specimen may appear. Thus I have always obtained from calcareous silicates rich in silicic acid (as oligoclase) a small quantity of silicic fluoride of calcuim; on the other hand, on analogous treatment of anorthite and wollastonite no needles of silicic fluoride of calcium were to be found. And the slow development of large gas bubbles on treatment of anorthite and wollastonite changed by HF was a proof that only a simple calcium fluoride had formed in the latter minerals. But by treatment of chondrodite, olivine and rhodonite with hydrofluoric gas and then with a cold drop of water, long prism-shaped silicic fluoride crystals of magnesium (iron) and manganese were produced.

## Illustrations of parts of Microscopic Preparations Showing

**(*a*) The silicicfluoride crystal types of metals appearing in petrologically important minerals and**

**(*b*) The characteristic changes which are effected upon the upper surface of thin sections or cleavage sections of petrologically important minerals either by hydrofluosilicic acid or by hydrofluoric gas.**

[PLATES I AND II.]

### *Explanation pf Plate I.*

[Note. In the reproduction of the plates, some of the Greek letters employed by the author to designate the figures have become indistinct. These Greek letters, however, are confined to Fig. 4, Plate I. The reader may restore them all by noting that the small crystals in "Fig. 1," of Plate I. are designated in the original from left to right in the following order: Alpha, epsilon, iota, rho, nu, mu, sigma, tau, which in the following explanation are designated by a, e, i, r, n, m, s, t]..

Fig. 1. Silicic fluoride of *potassium*, observed and represented when magnified to the 400th power: a, i, from the preparation of Prof. Stolba (by recrystallization on the object-glass); e, m, n, r, (∞ 0. ∞ 0 ∞, 0. ∞ 0∞.) from the water decoction of a dark-green biotite, changed by hydrofluoric gas. s. and t. are crystals formed by the recrystallization of silicic fluoride of *ammonium*.

Fig. 2. Silicic fluoride of *potassium* observed when magnified to the 400th power, and produced from the water decoction of amazonite from Miask changed by hydrofluoric gas.

Fig. 3. Silicic fluoride of *lithium*, magnified to the 200th power, and produced from the preparation of Prof. Stolba, by recrystallization upon the object-glass.

Fig. 4. Silicic fluoride of *sodium* (∞ *P*. *P*, ∞ *P*. 0 *P*.), magnified to the 400th power, and produced from the water decoction of albite from Zell (in Zillerthal) changed by hydrofluoric gas.

Fig. 5. Silicic fluoride of *calcium* (∞ *P*. 0 *P*, sometimes ∞ *P*. 0 *P*. ∞ Ᵽ ∞ etc.), seen as magnified to the 150th power, preparation of Prof. Stolba.

Fig. 6. Silicic fluoride of *calcium* magnified to the 200th power, and produced from the hot solution of the above mentioned preparation upon the object-glass.

Fig. 7. Short, hexagonal prisms terminated by truncated pyramids of silicic fluoride of *sodium* and slender branching forms or spindle-like forms of silicic fluoride of *calcium*, magnified 200 times, and produced by recrystallization of a mixture of two parts by weight of silicic fluoride of sodium and one part by weight of silicic fluoride of calcium.

Fig. 8. Long hexagonal prisms terminated by blunt pyramids of silicic fluoride of *sodium* and thick, branching, or spindle-like forms of silicic fluoride of *calcium*, seen as magnified to the 200th power and prepared by recrystallization of a mixture of one part by weight of silicic fluoride of sodium and two parts by weight of silicic fluoride of calcium.

Fig. 9. Silicic fluoride of *strontium*, observed when magnified to the 200th power, and produced from the preparation of Prof. Stolba by recrystallization upon an object-glass.

Fig. 10. Silicic fluoride of *magnesium* (for the most part $R$, $R . 0 R$), magnified to the 600th power and prepared from chondrodite—through the successive treatments of the latter with hydro-fluoric gas and hydrofluosilicic acid.

Fig. 11. Silicic fluoride of *magnesium* (for the most part $\infty P2 . R$, $R$, in part imperfectly formed) magnified to the 400th power and prepared from humite by treatment with hydrofluosilicic acid.

Fig. 12. Silicic fluoride of *magnesium* (for the most part imperfectly formed and regularly grouped crystals,) magnified to the 400th power and prepared by treatment of magnesite with hydrofluosilicic acid.

Fig 13. Rare crystals prepared from some calcareous silicates (corsite, tankite), by successive treatments with hydrofluoric gas and hot hydrofluosilicic acid, and observed when magnified to the 400th power. It is yet to be proven to which metal they belong. (The pyramidal crystals sometimes irregular at the middle edge, as well as the rhomboidal forms belong most probably to calcium).

Fig. 14. Tiny, short needles of silicic fluoride of *barium* and shrubby but yet delicate forms of silicic fluoride of calcium, brought out only by breathing upon them, (these forms are strongly stamped in the figure), observed when magnified to the 400th power and produced from a calcareous witherite—by treatment with hydrofluosilicic acid.

Fig. 15. Silicic fluoride of *iron* (mostly $\infty P2 . R$), magnified to 400th power and obtained from the silicic fluoride of iron preparation by recrystallization upon the object-glass.

Fig. 16. A thin section of *amazonite* from Miask which was covered with a drop of hydrofluo-silicic acid[1] and after drying of the drop observed when magnified to the 400th power. The cubes of silicicfluoride of potassium and the lattice structure of the amazonite are noticeable.

Fig. 17. Portion of a polished section of *oligoclase* from Ytterby, which was covered with a drop of hydrofluosilicic acid and after drying of the drop observed, magnified to the 400th power. Tiny six sided tablets of silicicfluoride of sodium, and thin spindle-like forms of silicicfluoride of calcium are noticeable.

Fig. 18. Portion of a polished section of *labradorite*, of changeable colors, probably near a *calcareously rich andesine*, the labradorite being from Ojamo in Finnland, was covered with a drop of hydrofluosilicic acid and

observed after drying of the drop, magnified to the 400th power. Short hexagonal prisms usually surrounded by a bubble of air, of silicicfluoride of sodium and tablet-shaped, rhomboidal and thorn-shaped forms of silicicfluoride of calcium are noticeable.

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[1] For all the specimens here mentioned the hydrofluo silicic acid was about 3½ per cent. strong.

Fig. 19. A part of a thin section of *labradorite* coming from the gabbro of Wolpersdorf, which was covered with a drop of hydrofluosilicic acid and observed after drying of the drop, magnified to the 400th power. The same crystal forms as in Fig. 18 are noticeable; but the spindle-shaped crystals of silicicfluoride of calcium are more numerous.

Fig. 20. A thin section of *anorthite* from the corsite from Corsica, which was covered with a drop of hydrofluosilicic acid and after drying of the drop observed, magnified to the 400th power. The same crystal forms as in Fig. 18 and 19 are noticeable; but the silicicfluorides of calcium are most numerous and the silicicfluoride of sodium most rare.

### *Explanation of Plate II.*

Fig. 1. A cleavage fragment of *albite* from Dauphiné, which was covered with a drop of hydrofluosilicic acid and observed after the drying of the drop when magnified to 400th power. Short hexagonal prisms of silicic fluoride of sodium and wedge-shaped etchings sometimes arranged in rows were noticed.

Fig. 2. Part of a polished thin section of *leucite* from Vesuvius, which was covered with a drop of hydrofluosilicic acid and observed, after drying of the drop, magnified to the 400th power. Many cubes of silicic fluoride of potassium, two hexagons of silicic fluoride of sodium and a thin rod of silicic fluoride of calcium were noticeable, besides the polygonally etched and creviced surface of the section.

Fig. 3. Part of a polished thin section of *elaeolite* from Laurwig, in Norway, which was covered with a drop of hydrofluosilicic acid and after drying of the drop observed when magnified to the 400th power. Hexagonal crystals of silicic fluoride of sodium, a cube (in the centre of the illustration) of silicic fluoride of potassium are noticeable, and also the coherent plate, divided only by coarse veinlets of segregated silica through which the texture of the elaeolite with its delicate parallel groovings and its crossed cleavage cracks appears.

Fig. 4. A thin section of *scapolite* from Malajo, in Wermland, which was covered with a drop of hydrofluosilicic acid and observed after the drying of the drop, magnified to the 400th power. The spindle-shaped crystal forms of silicic fluoride of calcium, hexagonal tablets, often enclosed in a bubble of air, of silicic fluoride of sodium, parallel cleavage crevices, and between the latter wrinkle-like etchings are observable.

Fig. 5. *Left half. Lithium iron mica* from Zinnwald which was covered with a drop of hydrofluosilicic acid and observed after drying of the drop, magnified 100 times. Many crystals similar to a very blunt six-sided pyramid, of silicic fluoride of lithium, a crystal in the centre of the figure, of silicic fluoride of iron, a few cubes of silicic fluoride of potassium and a single spindle-shaped crystal of silicic fluoride of calcium.

*Right half. Potassium mica* from Greenland, which, treated like the mica mentioned above, shows besides two hexagonal prisms of silicic fluoride of sodium and two crystals of silicic fluoride of iron, only crystals of silicic fluoride of potassium.

Fig. 6. A dark-green *biotite* which was treated in a manner analogous to that of the micas given above and observed when magnified to the 400th power: showed larger crystals and slender prisms of silicic fluoride of magnesium and silicic fluoride of iron next to little cubes of silicic fluoride of potassium.

Fig. 7. A thin section of *amphibole* from Luhov (near Milleschase) which was covered with a drop of hydrofluosilicic acid and observed, after the drying of the drop, when magnified to the 400th power. Larger crystals and slender prisms of silicic fluoride of magnesium and silicic fluoride of iron, two spindle-like crystals of silicic fluoride of calcium, a cube of silicic fluoride of potassium, a hexagon of silicic fluoride of sodium and parallel, slender, wrinkled etchings are noticeable.

Fig. 8. A thin section of *diallage* from the gabbro from Wolpersdorf, which was covered with a drop of hydrofluosilicic acid and after the drying of the drop, observed magnified to the 400th power. Numerous spindle-shaped crystals of silicicfluoride of calcium, larger crystals of silicicfluoride of magnesium and of iron and systems of parallel cleavage crevices running out in three directions are noticeable.

Fig. 9. Fragments of *bronzite* from Graubat in Steiermark, which were covered with a drop of hydrofluo silicic acid and after drying of the drop were examined when magnified to the 400th power. Large crystals of silicic fluoride of magnesium, and of silicic fluoride of iron, and the texture of the bronzite fragment with parallel groovings are noticeable.

Fig. 10. A thin section of *dichroite* from Orrijärfvi, in Finnland, which was covered with a drop of hydrofluosilicic acid, and after the drying of the drop examined. magnified to the 400th power Larger crystals of silicicfluoride of magnesium and irregularly arranged wrinkled etchings are noticeable.

Fig. 11. A thin section of a grain of *olivine* from Kozakov, treated in the same manner as is explained under Fig. 2, but delineated in all parts as magnified to the 400th power.

Fig. 12. A thin section of *olivine* from Kozakov (at Turnau) which was covered with a drop of hydrofluosilicic acid and observed when magnified from the 200th to the 800th power. The silicic fluoride crystals of magnesium and iron (drawn when magnified to the 200th power) the prominent pyramidal wholly parallel subindividual crystals, which appear magnified from 600 to 800 times, and the rhomboidal etchings of the entire surface of the sections are noticeable.

Fig. 13. The middle portion of a *chiastolite* crystal cut almost perpendicular to the main axis, treated with fluosilicic acid and examined, magnified from 200 to 400 times. Besides the central kernel with its rhomboidal outline the dark gray cross and the feather-like branchings of the coal-like substance parallel to the lateral edges of the prism, one notices only a few colorless particles of the unchanged chiastolite, while the greater part of the upper surface of the thin section presents a spotted or delicate undulatingly fibrous structure which in some places along the edge changes into net-like aggregates of parallel bars.

Fig. 14. Etchings upon *lithia iron mica* from Zinnwald, produced by the action of hydrofluoric gas and subsequent boiling away in water, and represented as magnified to the 400th power.

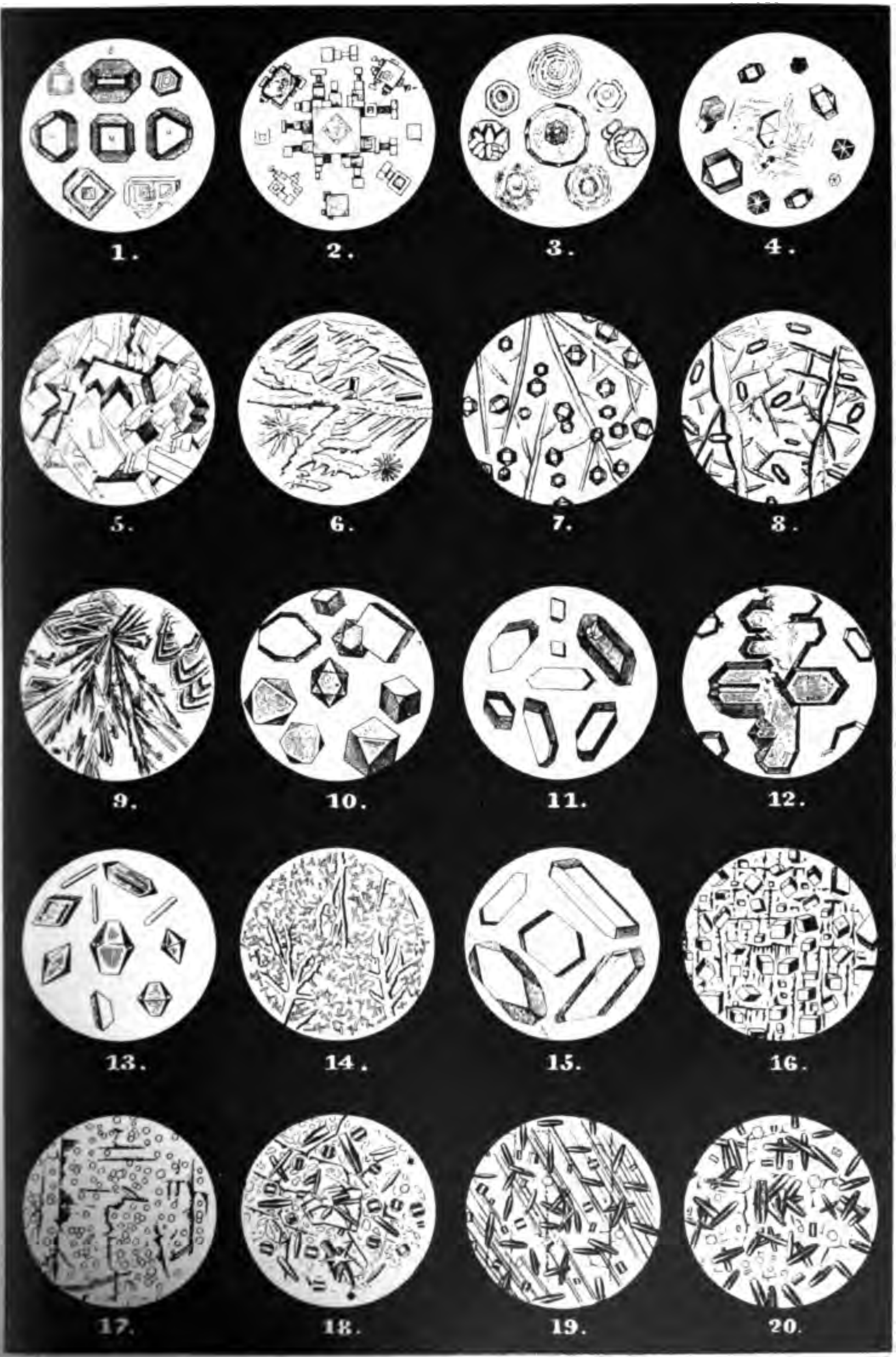
Fig. 15. A thin section of *elæolite* from Laurwig in Norway, treated with chlorine gas and observed, magnified to the 400th power. Cubes of of chloride of sodium which remain sticking in the remnant of gelatinous silica (not removed from the surface of the thin section), also the prism-shaped or long wrinkled etchings parallel to the main axis of the crystals and two large cleavage clefts running perpendicular to the main axis are noticeable.

Fig. 16. A thin section of *apatite* from Schlackenwald which was cut parallel to the base, covered with a drop of hydrofluosilicic acid and observed, after the drying of the drop, magnified to the 600th power. Striated aggregates of prismatic and acicular crystals are noticeable as well as uniform, dark particles of silicicfluoride of calcium, sometimes displaying an oblique angled cleavage and distinct hexagonal subindividuals of apatite (P. OP.), which sometimes display a beautiful scale-structure and are parallel or a little inclined to the main axis of the crystals. After successive boilings in water, by which the silicicfluoride of calcium is removed, the subindividual crystals of apatite appear most clearly.

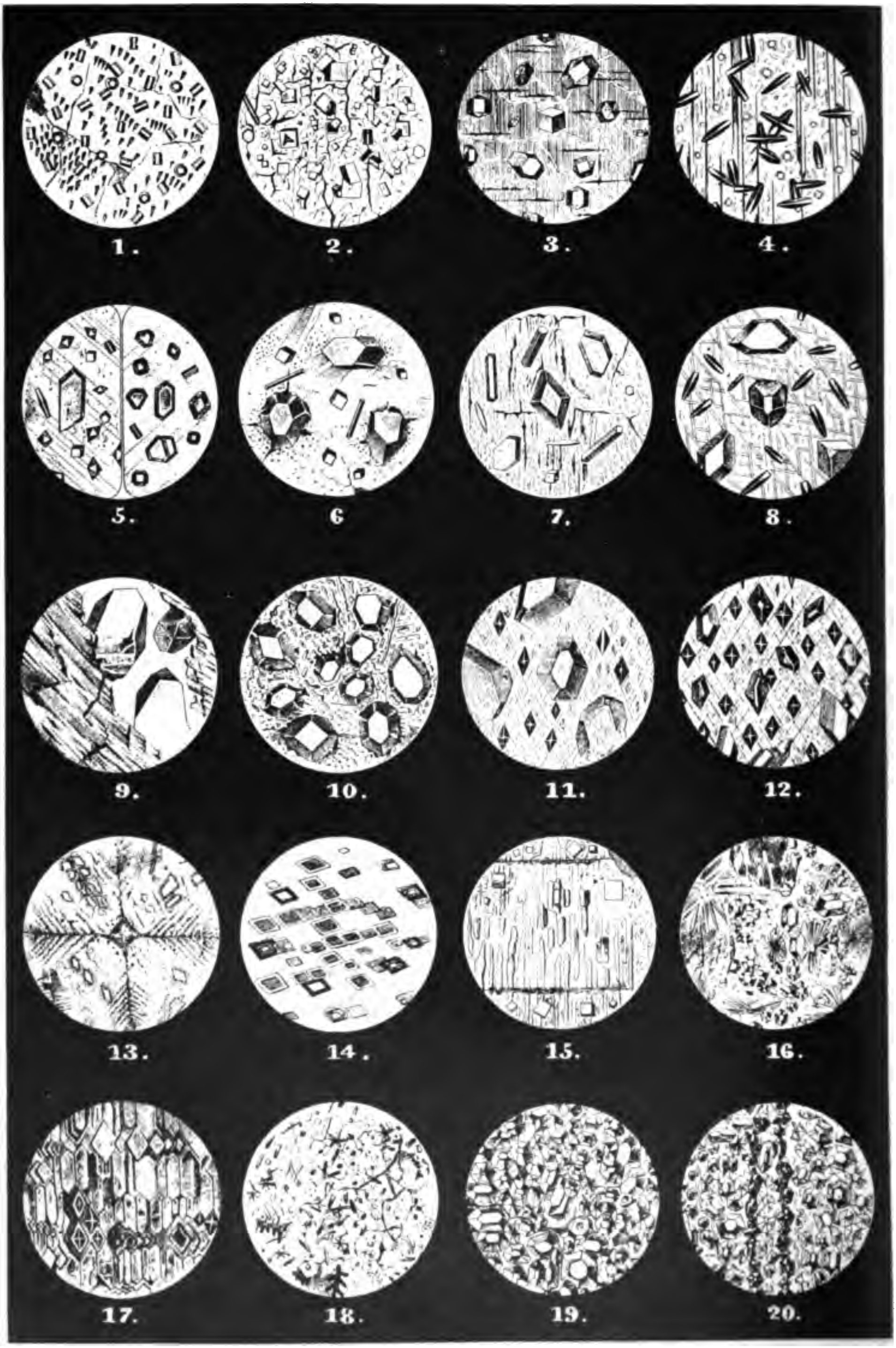
Fig. 17. A thin section of *apatite* from Zinnwald, cut parallel to the prism surface, boiled about 20 seconds in aqua regia and observed when magnified to the 600th power. Rhomboidal etchings of various lengths and solitary, prominent lateral edges of subindividual pyramid crystals.

Fig. 18. A thin section of *apatite* from Schlackenwald which was cut parallel to the base, treated with chlorine gas, covered with Canada balsam, furnished with a cover-glass and observed when magnified to the 400th power. Short, dark microlitic needles which cross each other in a horizontal position usually at an angle of about 60° and are probably to be regarded as edges remaining of subindividual crystals, of the uppermost stratum, furnished with long adherent bubbles of air. Among these, faint lateral outlines of the subindividual pyramid-crystals of the next lower stratum are visible.

Figs. 19 and 20. Thin sections of *apatite* from Schlachenwald, cut parallel to the base, treated with chlorine-gas, directly covered, not with Canada balsam, but with the coverglass, and observed when magnified to the 400th power. Both pictures illustrate the structure of the apatite crystal from little, hexagonal pyramid crystals (*P*, *P*. 0*P*), crowded closely together, sticking to each other, and almost parallel to the main axis. Upon those places of the apatite thin sections, which show no scale structure, the subindividual crystals are large and like thick tablets on account of the preponderance of the basal surfaces (Fig. 19). In the narrow scale zones, on the contrary, they are small and usually run out into pyramidal points. And the boundary lines of the scale zones consist of most extremely minute pyramidal crystals which are tolerably rectilinear and closely crowded together, as is shown by the two dark rows of crystals (boundary lines of the scale zones) of Fig. 20.



BORICKY'S MICRO-CHEMICAL METHOD.



1. 2. 3. 4.

5. 6 7. 8.

9. 10. 11. 12.

13. 14. 15. 16.

17. 18. 19. 20.

BORICKY'S MICRO-CHEMICAL METHOD.

# GEOGNOSTIC AND GEOGRAPHICAL OBSERVATIONS
# IN THE STATE OF MINNESOTA.

# GEOGNOSTIC AND GEOGRAPHIC OBSERVATIONS IN THE STATE OF MINNESOTA.

BY DR. J. H. KLOOS.

[Extracted from the the *Zeitschrift der Gesellschaft für Erd kunde zu Berlin*. Bd. XII. 1877. Translated by N. H. Winchell].

[NOTE. In two former reports, the tenth and eleventh, have been given translations of a part of the work of Mr. Kloos, based on observations and collections made by him in Minnesota before the beginning of the present survey. The following paper is not given entire, but only such additional facts and discussions as are not found in the former papers. In this connection attention may be called to the more correct description of the "Silurian" strata at St. Paul, the record of a well driven at the Northern Pacific crossing of the Red River of the North, at Moorhead, the petrographical notes on the crystalline rocks, and on the slates at Thompson, and the paleontological remarks on the Lingulæ at St. Croix Falls.

Mr. Kloos, in a communication to the translator, dated Stuttgart, Württemberg, Sep. 13, 1885, criticises the translation of his remarks on *Owen's Report of a Geological Survey of Wisconsin, etc.*, (Tenth report, p. 175), viz: "You have remarked that I said, 'a fault of the work is its petty simplicity,' which, as it seems to me, is not quite the meaning of 'Ein Mangel des Werkes ist seine geringe Uebersichtlichkeit.' Petty simplicity means, in the German language, *Kleinliche Einfältigkeit*, which is not rather flattering for an author, and which not at all expresses my opinion of Owen's work. On the contrary this work was very valuable, and almost grand, considering the time it was written, but it contains too much, and the geology is wrapped up in so many detailed topographical descriptions that it becomes difficult for a geologist of modern times to find his way through the long pages.

"I allow that it is very difficult to give the exact meaning of 'geringe Uebersichtlichkeit,' and I am only able to translate it at some greater length, for instance: 'A fault of the work is its arrangement, which makes it rather difficult to acquire a general view of its contents.' I would be pleased if in a future publication you could find an opportunity to say something on this subject, as I am afraid that the American geologists have felt hurt in reading my opinion of Owen's work." The translator is very glad of the opportunity to correct, on the authority of the author, such an error in the former translation, as it involves the opinion held by one geologist of the work of another.]

### THE RED RIVER OF THE NORTH.

* * * There are present all the indications that the Red river of the North, at some earlier time, yet geologically not very far distant, has had a southerly course, and emptied into the Mississippi through the Bois des Sioux river, lake Traverse, Big-Stone lake and the Minnesota or St. Peter river. The small space of land between these two lakes last named, from which the water runs in opposite directions, is entirely flat, and rises but little above the shore of either lake. It happens frequently in spring, when the mouth of the Nelson river, in the far north, is stopped by accumulations of ice, that this strip of land, as well as a large tract of the prairie along the western border of the state, is overflowed, and that then is formed one extensive lake,—so much so that a flat-bottomed steamboat was got across the flooded water-shed, from the St. Peter river into the Red river of the North.*

For an explanation of the above-mentioned change in the direction of a part of the gathered waters of western Minnesota, it is only necessary to suppose a slight elevation of the land to the north, or which is more likely, that since the glacial epoch a sinking of a few feet has taken place.

Corroborative of this hypothesis, reference may be made also to all the rivers and creeks in the northern part of Minnesota, which, coming from the north, turn at a sharp angle toward the west and empty into the Red river of the North, having rapid and impetuous courses; while the Bois des Sioux river, with a northerly course, is a very slow flowing stream. The Red river itself also flows slow, and numberless are the curves and angles which both these rivers describe. It is only necessary here to introduce a slight change in order to give the waters of this very level prairie an exactly opposite course.

### THE DRIFT IN MINNESOTA.

* * * The drift deposits through all their great extent, in their totality, remain tolerably uniform. This is specially the case with the preponderating clayey portions, which everywhere lie directly on the older formations, occupying the lowest part of the diluvium. It exhibits, in this respect, a certain analogy to the drift-clay and marl of Germany (in upper Schleswig, Pommerania, &c). These clayey parts are not always present, but the sand and gerölle, which in normal order

overlie the clay, are still more frequently wanting. The clay, on the other hand, often reaches a thickness of 100 to 120 feet, and in its lower parts generally is of a bluish color, though of a yellowish or brown color in the region of lake Superior, and nowhere contains organic remains, although very often small rounded pieces of limestone and fragments of slate.

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*This probably refers to the attempt of Capt. Davis, in 1859, which was not quite successful.—N. H. W.

I found everywhere in the western part of the state, in the calcareous clays which there constitute the basis of the prairie, little rounded white limestone fragments. If these be broken they show within the structure of a pure dolomitic limestone of a yellowish brown color. Only rarely does one see small rounded fragments of granitic rock, while the limestone pieces always far predominate.

The clayey portions, (by the inhabitants called 'hardpan' on account of their firmness and hardness,) form the sub-soil throughout the prairies and the woodland, as well as the gently undulating well-watered table-lands; while the accumulations of sand and gravel form a very distinct terrane with many isolated rather high ridges. The gerölle of this latter formation exhibits a great diversity, and besides Silurian limestone in more local accumulations, consists of the crystalline rocks and slates which in the far north are found outcropping at the surface. In the sandy, very hilly tracts, are also found many large erratic blocks, which are wanting upon the prairies, though they are found in great numbers about the fresh water lakes which occupy the depressions in the sandy and stony diluvium.

Concerning the origin of this clayey deposit, with no trace of organic life, as yet no established theory has been accepted, it is very generally considered to be the material transported by glaciers, including with it the sand, quartz and gravel which is spread over it. But in what way the process was carried on, by which the fine clayey parts were separated from the granular and siliceous, is not entirely understood. In the clayey diluvium, furthermore, are those lakes the water of which has a bitter salt taste, and is unfit to drink. These are in the western part of the state, but restricted to the characteristically prairie portions. Here, and specially north from the St. Peter river, the surface of the earth is rich in salts, and for miles can be seen a white, bitter-tasting salt-crust, forming the surface, while all wells, even to a considerable depth, give bad water.*

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*This bad water was largely due to the use of pine planks for curbing, the pitch in which was acted upon by the alkaline salts in the waters, and has been greatly modified since the use of pine for curbing has been abandoned.—N. H. W., Compare the Sixth Annual Report.

The above-described light colored diluvial clay with small limestone gravel, which forms the subsoil of the wide prairies on the Red river, possesses, in the interior of the American continent, a great extension. It is apparently identical with the yellow marl, or "bluff formation," which F. V. Hayden describes in his work on the geology of the upper Missouri, and which in several places has afforded the bones of the mastodon and elephant as well as land and fresh-water shells.

The extensive and thick beds of clay which cover the Huronian and the lower Silurian rocks about lake Superior, are by some geologists considered as of the same age as the above diluvial clay of the northwestern states, for example, Winchell in his geological reports. Others, however, ascribe to the light colored non-laminated clay, (the true "hardpan") containing small gravel a later date than to the dark-red clays about lake Superior, which more frequently show a bedded structure.* I have not been able to learn of any direct superposition of one over the other.

The lake Superior diluvium differs from "hardpan," by its very marked deep red color, and a greater thickness. I have seen on the lower course of the St. Louis river, a section of this clay amounting to 500 feet. It seems also to be completely free from stones, but exhibits often a plainly bedded structure, and changes often to sandy and gravelly beds.

The diluvium in southern Minnesota has a great thickness. Along the boundary of Iowa the Silurian limestone is covered only by a few feet of sandy beds, and even seems to afford a region where the drift is wanting entirely, without exhibiting any of the characteristics of its southern boundary, which are to be found much more evident in the neighborhood of the Ohio river.

Yet in the central part of the state, by means of wells, the great thickness of this post-tertiary deposit is known. From a well which was drilled a few years ago on the Northern Pacific railroad where it crosses the Red river, I obtained the following record of the layers passed through:

3 feet (English), black earth.

92 feet clay (marl?) evidently colored, with a few limestone pebbles.

10 feet gravel.

115 feet hardpan, firm clay mixed with coarse gravel.

30 feet white clay beds.

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* Whittlesey on the fresh-water glacial drift of the northwestern states.

12 feet red coarse sandstone (looks like the Potsdam sandstone).

The river itself here has cut only to the depth of forty-five feet into the surface of the earth, and the shores attain nowhere a very much greater hight. It is hence questionable whether the whole thickness of 260 feet, of this section, belongs to the post-tertiary formation; rather I should be inclined to assign the deeper portion of it, and specially the 30 feet of clay-beds, to the Cretaceous formation, of the appearance of which at points not very far removed from this place, there will be a special description later. * * * *

## THE LOWER SILURIAN ON THE UPPER MISSISSIPPI.

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I shall have opportunity later to return to the lower sandstone, in giving a special description of the beds on the St. Croix river. Owen has called it the "lower Silurian sandstone of the upper Mississippi," distinguishing the dolomite as "lower magnesian limestone." The characteristic fossils of the sandstone are trilobites, belonging to the genera *Dikelocephalus* and *Conocephalus*, also bivalves, *Lingula* and *Obolus*, which in the vicinity of Taylor's Falls completely fill whole layers. In the crumbling sandstones of Minnesota it is difficult to find determinable fragments of trilobites. Relying on observations in Wisconsin, Owen distinguishes six trilobite-layers, which are separated from each other by layers from ten to a hundred and fifty feet in thickness, of the existence of which, however, Hall, still later, expresses doubt. In the magnesian limestone, up to the present time, have been found only insignificant, scarcely recognizable traces of fossils. They are small *Lingulæ*, stony forms of univalves, which are the modified remains of *Euomphalus* and *Ophileta*, and fragments of trilobites similar to those in the sandstone. The geological horizon of the lower dolomite must therefore be reckoned to fall in the time between the Potsdam sandstone and the strata of the Trenton.

* * * * * * * * *

The city of St. Paul is, in general terms, built on two terraces, of which the lower consists of the St. Peter sandstone, which is covered and protected by limestone layers but a few feet thick. The upper terrace is formed by the upper part of the Trenton, and upon that lies the drift. A long-extended series of hills, composed of heavy drift, very largely made up of limestone fragments, surrounds the city on the north, the west and the northwest, while toward the south and the south west the terraces descend abruptly. From the present river channel these are separated by a tract of low, principally overflowed land. The lower limestone layers which are often broken and removed from their original position, contain numerously the fossil *Strophomena alternata*, of Conrad. The valves of this large shell are, as in the Cincinnati limestone, chiefly accumulated in certain beds, and cover the surfaces of the layers in hundreds. These are the "*Producti*" which W. H. Keating, the geologist and historiographer of Long's expedition in 1823, mentions at Fort Snelling.

There are also in these lowest beds of the Trenton limestone, *Ctenodonta nasuta* Hall, agreeing with the figures in Dana's Geology of 1864 as well as in the geological report of Canada (in French) published in 1864, page 187, fig. 166; *Bellerophon bilobatus* Sow. (J. Hall in Palaeontology of N. Y., vol i, pl. 40, fig. 3), and a little crustacean, apparently *Leperditia fabulites.* Further up the river, at Minneapolis, I gathered from this same limestone,

*Murchisonia bicincta* Hall, Pal. N. Y., pl. 38, fig. 5.

*Pleurotomaria lenticularis* Conrad, N. Y., pl. 37, fig. 6.

*Subulites elongata* Conrad, N. Y., pl. 39, fig. 5, and Geol. Rep. of Canada, (French), 1864, p. 194, fig. 179.

*Orthoceras juncium* Hall.

*Orthis tricenaria* Conrad (also at St. Paul), Geol. Rep. of Canada, (French), 1864, p. 176, fig. 151.

Unfortunately the fossils that occur in the very hard rock appear only as casts, and I was obliged to undertake the examination with only such, excepting in the case of *Strophomena alternata.*

At the foot of the above-mentioned upper terrace, in the midst of the city, are the stone quarries which supply building material for St. Paul as well as for several other cities on the upper Mississippi. In these quarries the successive strata of the dolomitic limestone are disclosed to the depth of thirty or thirty-five feet. Here are firm horizontal layers of a bluish color, spotted here and there with darker, and appearing to be penetrated by evident calcite. Fossils are rare in this middle portion of the Trenton, with the exception of impressions of fucoids (*Buthotrephis*) which I saw on several of the layers. The impressions agree best with the figures of *Buthotrephis*(*Licrophycus*) Bill. *succulens* Owen, in Dana's Geology, and in Hall's Pal. of New York, vol i, pl. 22, fig. 2a. Several larger forms might answer for *Palæophycus rugosas*; Owen thought these were too badly preserved to permit an exact determination. Besides these plant-remains I found, in my frequent visits to these quarries, only impressions of *Orthis tricenaria*, *Pleurotomaria* and a species of *Lingula*.

Above the blue limestone follow five or six feet of clayey and marly beds of a dirty-yellow color with many, though poorly preserved remains of fossils. *Strophomena* is again of frequent occurrence, as well as *Orthis tricenaria* and a species of *Murchisonia*. In color and composition these marly beds are hardly distinguishable from the lowest beds, which lie directly on the sandstone. The highest beds of the Trenton group appear in some of the bluffs of the streets in the higher parts of the city, lying directly under sixty to seventy feet of gravel and sand. These streets at the time of my residence there had been but little worked. These beds are very rich in organic remains, especially if the forms that are not very different could be known. Thin plates of dense crystalline limestone alternate with the marl beds which crumble down in the air, the latter being of a dirty-blue color. The entire slope was covered with disintegrated shale, in the midst of which were scattered thin limestone slabs of evident crystalline structure, which swarmed with beautiful coral-like bryozoa and small brachiopods. The most beautiful, most delicate forms of the palæozoic sea lie here in numberless specimens loose in the clay, or without any difficulty separable from the surface of the rock at the limestone quarries. Bryozoa, crinoid stems, head and tail shields of trilobites, with little Rhynchonellas, Terebratulas, Leptæna, Orthis and several gasteropods form the fauna.

The same fossils are found on the opposite bank of the Mississippi; only the bank is entirely wooded, and the higher beds are not exposed. But fossils can be gathered along the foot of the lower bank, where every rainstorm washes them down the numerous little gutters on the bluff. On both banks I have found the following named species common.

*Stenopora (Chætetes) fibrosa* Gold. spec.
*Chætetes lycoperdon* Say.

These bryozoa are represented as *Calamopora* in Goldfuss' *Petrefakta Germ*, plate 64, figs. 9 and 10. Hall, in Pal. N. Y. vol. i, plate 24, fig. 1, considers the branched form (*Ch. fibrosa*) and the hemispherical form (*Ch. lycoperdon*) as belonging to the same species, which opinion I can confirm by the specimens gathered at St. Paul. The cell-structure in them is exactly the same, and transitions from both forms are quite common.

*Petraia* (*Streptelasma*) *corniculum* Hall, (Pal. N. Y. pl. 25, fig. 1).

*Rhynchonella recurvirostra* Hall, (Pal. N. Y. pl. 33, fig. 5).

*Rhynchonella increbescens* Hall, (*capax* Con., Pal. N. Y. pl. 33, fig. 13, a, b, c, d, p, r, s). Geol. Rep. of Canada, French, published in 1864, fig. 153.

This is the most common brachiopod in the upper strata. The very distended varieties of this species, which are so common at Cincinnati and other localities of the Trenton, I have not yet been able to find—nor *Orthis lynx*, their constant companion in Ohio.

*Strophomena deltoidea* Con., (Hall, Pal. N. Y. I. pl. 31, fig. 3).

*Strophomena sericea* Sow., (Hall, Pal. N. Y. pl. 31, B. 2).

*Orthis testudinaria* Dalm, (Geol. Rep. of Canada, French, published in 1864, p. 175, fig. 144).

Chonetes lata.

*Schizocrinus nodosus* Hall, (Pal. of N. Y. I. pl. 27). Stem joints in great numbers.

*Leperditia*, spec.?

*Ptilodictya*, spec.?

*Calymene senaria* Con. (blumenbachii).

Illænus. Asaphus and Phacops. Head and caudal shields.

The remains of trilobites are comparatively rare; but there are present numerous specimens of *Calymena senaria*, though not nearly so many as at Cincinnati.

These fossils have all been collected by Logan from the Trenton beds in Canada, and by Hall from beds of the same age in New York. They are also well known, for the most part, from the Llandeilo flags of England.

Hall remarks that on the upper Mississippi and at the Falls of St. Anthony, the lower part of the Trenton group as it is developed in the eastern part of the United States, the Birdseye, Black River and the Trenton limestone proper, can also be distinguished.

So far as Minnesota is concerned, this must be wholly erroneous, and it would be difficult to distinguish in the upper magnesian limestone three parts that are palæontologically and petrographically distinct. The fossils taken together point to the level of the proper Trenton limestone, and some extend much higher in the Hudson River group, though they are not found in the lower beds in the eastern states. While the thickness of the Trenton group in New York is said to average about

300 feet, that of the limestone beds, with alternating sheets of shale, lying above the St. Peter sandstone, at different points in Minnesota, amounts only to 25 to 50 feet.

Of the Lower Silurian strata of the eastern states, only the Potsdam sandstone and the Trenton limestone have been identified on the upper Mississippi with certainty. The intervening formations, which in the east are predominatingly limy (Calciferous sandstone, Chazy, Birdseye and Black River limestone) are represented in Minnesota by the lower dolomitic limestone and the St. Peter sandstone, from the former of which, as yet, only doubtful remains of gasteropods and of trilobites have been obtained, while the sandstone is entirely destitute of fossils.

In the eastern part of St. Paul, the horizontal limestone beds are suddenly broken off, while the sandrock is entirely washed out. An interval extending up to the next range of bluff (Dayton's Bluff) about a quarter of a mile, is filled with immense heaps of debris. It is a mixture of sand and limestone *gerölle* which has been shattered and cut through by running water. On the other side of the Mississippi also the same formation is found extending out to the Silurian bluffs. To judge from the amount and the mixed nature of this gerölle, the waters from the upper plains adjoining the town must, in former times, have gathered tumultuously into this valley; and this extension to the further shore of the river certainly cannot be assigned to a date before the Mississippi had acquired its channel through the Silurian strata. Through the thickest part of this mass flow still two creeks, with a strong current, viz., Phalen's creek and Trout brook. Along the former passes the Lake Superior railroad, in order to reach the level of the surrounding country, while the St. Paul and Pacific road, coming from the west, found its only approach to the capital through the valley of Trout brook, and is compelled to describe a great curve in reaching its depot on the bank of the river. This is likewise the only route which the great Northern Pacific road had to take in order to connect with the lines to Chicago and New York, which, during the winter months, constitute its only means of communication with the east.

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## THE ARCHÆAN FORMATION ON THE UPPER MISSISSIPPI.

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The massive crystalline rocks of the upper Mississippi and Sauk river show a great similarity in their composition. In the first place are the syenitic granites(micaceous amphibole-granites[*]) which form sometimes long, rounded, gently ascending ridges, and sometimes low rock-crags. In these rocks a bluish-white translucent feldspar (orthoclase) is abundant, which lends to the rock a bluish color. The hornblende is of a dark-green color, and appears in irregularly outlined shapes. On the borders these are covered with mica scales, which sometimes surround the hornblendes, and sometimes stand out from them. The mica appears most generally not as an original ingredient. Quartz, in very small grains, is apparent everywhere. Plagioclase, also is not wanting. In short intervals, between the heavily wooded ranges of hills that contain these rocks, rocky knobs jut out in the swampy meadows, which consist of syenite. The feldspar is reddish orthoclase, with more hornblende Quartz and mica are sparingly present. The latter always stands in close association with the hornblende.

A very beautiful syenite granite forms the reef at the mouth of Sauk river, which here gives rise to the so-called Sauk rapids. It is a variegated rock in which sometimes a blue and sometimes a red color prevails. It contains everywhere two kinds of feldspar—besides red and blue orthoclase, a considerable quantity of greenish plagioclase showing evident striation; black hornblende, a little mica and quartz. The hornblende is sometimes in separate masses as large as a foot in diameter.

Three small parallel dykes of a dark, fine-grained rock pass perpendicular through the syenite, with sharp outlines, and also can be followed on the opposite shore. But here, singularly, the adjoining rock is not syenite but a very hard granite-porphyry with large crystals of feldspar, the relation of which to the syenite it was not possible further to discover. Under the loup the ground-mass of the dark dyke-rock resolves itself into a mixture of a feldspar and an augitic mineral. Very beautifully and finely striated feldspar-plates are distributed porphyritically. The microscopic and chemical examination of this rock has placed its relationship with the melaphyrs[†].

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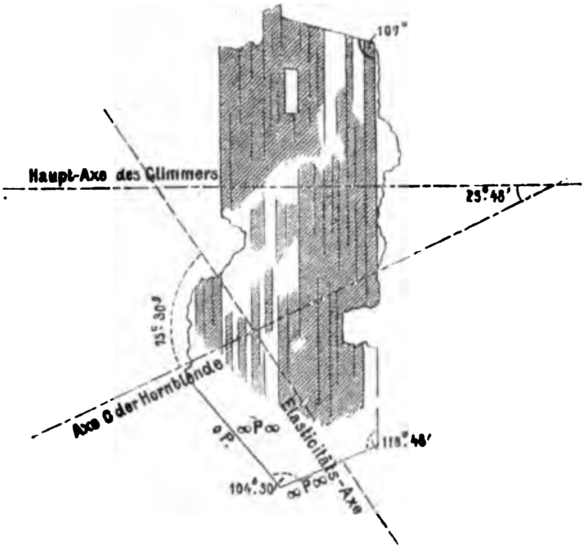
[*] H. Rosenbusch. *On granitic rocks*, in the *Zeitschrift d. d. Gesell*, XXVIII Bd., 2 Heft, S. 370 u. 371.

[†] In *Leonhard's Jahrbuch*, 1877, parts 1, 2 and 3, are set forth the complete microscopic and chemical characters of the massive crystalline rocks which I brought from Minnesota, whose investigation my esteemed teacher, Prof. Streng, of Giessen, had the goodness to undertake, some years ago; and in connection with the same are discussed the geological relations so far as it was possible to determine them, for which reason I here add nothing further on that subject. [See translation of this in the 11th report.—N. H. W].

Six miles further north, at the little town or Watab, (formerly a well-known point for trade with the Indians,) still another rock appears. The ridges here become higher and more conspicuous, but at the same time more heavily wooded and the rock outcrops less evident. The rock samples brought from Watab consist of quartz and augite dioryte along with syenite-granite and several varieties of hornblendless granite. Unfortunately the outcrops here are too few to make it possible to come to a conclusion as to the structural relations of these rocks with each other. On the spot one can only come to the conclusion that the granitic rocks outcrop as dykes in the quartz-dioryte, and that there is a greater extent of the latter than of the former.

A fine-grained rock from Watab, which is not treated of in the work in Leonhard's Jahrbuch, referred to on page 22, is abundantly pierced by blades of feldspar, and, even under the loup, shows much colorless feldspar and dull quartz along with a dark mineral (hornblende?) and a little tombac-brown mica, gave the following microscopic characters: In a clear groundmass, clouded only in spots here and there, lie the forms of green and brown crystals. Both are strongly pleochroic; the green become grass to yellowish-green, and show little absorption; the brown play from dark brown to light yellowish-brown, with strong light absorption. The regular six-sided sections



The faded portions indicate mica. The numbers and characters pertain to the hornblende.

of the latter mineral remain, at crossed Nicols, completely dark. The rectangular diagonal sections polarize brightly, and exhibit a lamellar structure. The green mineral has the cleavage of hornblende, the brown is mica. Hornblende and mica are often interchangeable, which appears here very evident by the difference of color.

Generally the mica lies about the margins of the hornblende, and surrounds it more or less regularly. In one case was to be seen a very beautiful interchange between hornblende and mica through a space of 0. 8 $^{mm}$ by 0. 3 $^{mm}$ as exhibited in the foregoing figure. By measuring the angles, and noting the position of the line of extension it was possible to determine that the principal axis of the mica forms an angle of about 23 degrees with axis C of the hornblende.

In polarized light the clear groundmass is resolved into individual grains of feldspar and quartz, the latter polarizing brightly and forming the cementing material between the feldspars. The latter are mostly twinned, sometimes clouded and sometimes not; some of them striated, others not. Often, of two or three individuals standing in the position of twins. one shows a striation and the others polarize singly or as units. Orthoclase is decidedly predominant. Quartz and orthoclase are filled with long needle-shaped microlites which are altogether colorless and pellucid, and have the aspect of apatite These needles, whose abundance is remarkable, penetrate also the hornblende and the mica. They show, under higher power of magnifying, evident polarization, are very often fractured, and for the most part are feebly bound together.

The rock is cut by feldspathic veins, which consist prevaililgly of clouded orthoclase although scattered plagioclase and irregular outlined grains of quartz also are visible. It is remarkable that here the apatite needles are wanting. Moreover the microscopic field furnished also some scattered minute reddish-brown clouded sections which are doubly refracting and may be titanite. There is a sprinkling also of pyrite.

This rock is accordingly a very finegrained magnesia-mica amphibole-granite, with more hornblende than the other granitic rocks of the upper Mississippi possess.

At Watab there are also melaphyrs which may sustain the same relation to the syenite-granite as at Sauk Rapids. Only here the formation is difficult to investigate, and the heavy forest, which afforded only isolated exposed points for observation, made it impossible in the limited time which I could devote to this point, to determine certainly a dyke-like manner of outcrop, such as is plainly exposed at Sauk Rapids. The melaphyrs brought from Watab are very hard and compact, under the loup of an entirely felsitic aspect; and the microscope has already revealed in them a triclinic feldspar, a greenish, somewhat changed augite and magnetite.*

* * * * * * * * *

North from Watab the banks of the Mississippi, for a distance of twenty miles, furnish, again, no outcrop of rock. At the village of Little Falls, which is twenty-seven miles distant from the mouth of the Sauk river, the stream takes its way through a wide zone of mica schists and crystalline clay slates, which are developed to some extent as a good roofing-slate. The dip of the outcropping layers is toward the northwest, from 65° to 72° while the slates have a dip in the opposite direction from 70° to 80°.†

The rock overlying the schists consists of roofing-slates, that underlying is the mica schist next to be described. Between these lie micaceous clay-slates. Inasmuch as the schists which prevail from this place southwardly, on account of the fine distribution of the mica scales, have the aspect of a fine-grained gray gneiss, and it was of great importance, on account of its resemblance to another Archæan rock. to determine the presence or the absence of this kind of rock on the Mississippi, I had two slides made of the mica schist, one parallel with and the other perpendicular to the schistose structure. Under the microscope the predominant mica scales appear, in the former slide, in a colorless, pellucid groundmass, having six-sided outlines and a dark brown color. They remain dark at crossed Nicols; while the irregularly four-sided and the rectangular, long, diagonal sections exhibit a lighter color, a strong pleochroism and an evident lamellar arrangement. In the second slide the long, striated sections of the mica lie in a more or less parallel position, and between them are visible still a much greater number of wedge-shaped mica blades which, on account of their minuteness, appear colorless and do not afford any means of detecting any pleochroism. There are, however, also some blades which, parallel to 0P, remain dark at crossed Nicols.

In polarized light, and especially at crossed Nicols, the ground mass is resolved into clear, regular polyhedrons of quartz, those of the same size ranked together. The appearance is much like that of a mosaic, and it is very interesting that in this respect both slides perfectly exhibit this structure. Hence it is very plainly demonstrated that the schistosity is dependent entirely on the position of the mica scales.

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*Eleventh annual report, page 50.—N. H. W.

†The dip of the slates is given by Owen (l. c. p. 166) as the dip of the formation. The bedding lines were nevertheless plainly to be seen, and were evident, furthermore, by parallel bands of milk white quartz.

The quartz is relatively poor in cavities, though with a power 475 diameters I could distinguish some isolated fluid-cavities with moving bubbles.

Besides quartz and mica, the microscope brought to light in this schist only some grains of magnetite; of feldspar no trace can be distinguished, nor of apatite. The absence of feldspar shows that here we have to do with a genuine mica-schist, though this rock has formerly been conceived by me to be a gneiss, and has been so noticed.* The great roll which gneiss plays in the Archæan formation in America as well as in Europe, makes the absence of it on the upper Mississippi very remarkable, and warrants the opinion that it will still be found under the drift deposits.

In connection with this very evidently bedded mica-schist, at the place last mentioned, appear some diallage-diorytes, formerly described, which in the work referred to, were designated augite-diorytes.

South from the village the dioryte rises in the midst of the river-bluff, in low, broken cliffs, at the foot of which a stream has its entrance. Further up this stream also diorytes are again met with in the bed of the creek. These also contain diallage and are very fine-grained. The two places where these rocks outcrop are separated by low swampy ground, but are distant from each other only a few hundred paces, wherefore a continuation is probable without any intervening schist. Furthermore, in both these rocks, in hand-samples, it is possible to observe transitions in which the characteristic crystals of diallage appear surrounded by an outer band of hornblende.

Inter-stratified with the crystalline micaceous clay slates, are small lenticular masses of a granular hornblendic rock, which, both by its chemical and its microscopic characters, is found to be a quartz-dioryte. These lie parallel to the schistose structure, which conforms to their contour, measure from a few inches to over two feet, and have, especially about their margins, great numbers of little garnets; while the inside is a cavity whose walls are often lined by quartz crystals.†

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*See Leonhard's Jahrbuch, 1877, p. 36. *On the crystalline rocks of Minnesota in North America*, by A. Streng and J. H. Kloos. Also compare the Eleventh report, p. 34.—N.H.W.

†*On the crystalline rocks of Minnesota*, by A. Streng and J. H. Kloos. Leonhard's Jahrbuch, 1877, p. 36. Compare also the Eleventh annual report, p. 34.

North from Little Falls, the rocky strata disappear again under the sandy prairie; soon the river banks become completely wooded and afford nothing of geological interest. Rocky outcrops are first seen again at the falls of Pokegama, ninety miles further north. Here are beds of granular sandstone, or quartzyte, the age of which has not yet been determined.

### THE CRYSTALLINE ROCKS OF THE SAUK VALLEY.

The Sauk river, which has already often been mentioned, cuts from east to west through the belt of crystalline rocks, of which we have already ascertained the foregoing facts, and and which outcrop at its mouth. Westward from the Mississippi, the first rock-exposure is at a distance of three and a half miles. Here are again low knobs of a red granite, having magnesia-mica and amphibole. Thence for twenty-five miles are long ridges of granitic rocks, heavily wooded. The intervening valleys are filled with drift, which has given origin to a series of ridges that rise from the sandy prairie. The most favorable exposures are at the villages of Rockville, where a very coarse-grained granite has wide extent, and Cold Spring, where in company with this is found a fine-grained porphyritic variety. The coarse-grained granite, different from any outcropping on the Mississippi, constitutes the prevailing rock at Richmond, where it is seen not to cease but to extend over the surrounding country, outcropping in the creeks and through a coarse debris which consists of orthoclase crystals, fragments of quartz and disintegrated mica. At Richmond is found again a dark, fine-grained augite-dioryte, of which the chemical composition, microscopic characters and relative position in the rocks have already been published in the work referred to.*

These rocks cannot be followed further west than Richmond. This village is situated at the border of the western prairies which the eye cannot span, where all geological investigations have to cease. Only at one point, near the village of Sauk Centre, forty-three miles west from the Mississippi, is there an upward swell or undulation, of the rock through the covering of earth. Here is a low ridge of crystalline rocks. A little quarry, opened by the German farmers for the purpose of getting stone for the foundations of their houses, has disclosed two different rocks; one a granite which for the first time exhibits a somewhat gneissic structure, and the other a quartz-dioryte. The whole outcrop is only sixty to seventy feet wide, and disappears in all directions under the grassy plain.

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*Leonhard's Jahrbuch, 1877, p. 37 and 118; also, see my paper in Silliman's Journal, 1872, pp. 18-20.

There is no doubt that the crystalline rocks of the Mississippi and the Sauk river belong to the Laurentian formation, and that the above described outcrops form only isolated points of observation in a wide belt of that formation which passes through Minnesota from north to south. The connection with the more extensive outcrops of Laurentian rocks in the northern part of the state is, nevertheless, as yet, only conjecture, and so it will remain, indeed, for a long time to come. Whether the crystalline schists at Little Falls should in like manner be placed in the Laurentian, or be considered to represent the Huronian, must likewise remain at present undecided. From the Laurentian rocks, as they are developed in Canada and Michigan, north and south of the great lake, those on the Mississippi differ notably in the lack of gneiss and crystalline limestone, although the presence of the latter in that region is indicated by great rolled fragments which I met with, particularly north of the Sauk river. With the Huronian also, as those rocks are described on the north shore of lake Huron, the schist-complex at Little Falls does not agree, inasmuch as the great conglomerates are wanting which are described by the geological reports of Canada.* The Huronian in the western part of Minnesota also is different, as we shall see below, and resembles more the beds of that age in Wisconsin and Michigan.

In a southerly direction the Laurentian zone is again met with on the St. Peter river, seventy miles distant. Owen describes from there, between the mouth of the Cottonwood river and the Redwood, granite and syenitic rocks extending over forty-five miles. These have been described more recently by N. H. Winchell in his second report. At several places they appear to take on a gneissic structure, and to pass into hornblendic schist.** The resemblance of the granite to that at St. Cloud he calls attention at several places. In the vicinity of Granite Falls and Patterson's rapids, on the St. Peter river, the granite is cut by dykes of trap and greenstone which can be followed for a distance of half a mile.†

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*In the reports for 1864 of the Canadian geological commission, at the base of the Huronian system on the Thessalon river, north of lake Huron, are mentioned chloritic schists which alternate with diorytes, and therein appear to present a greater analogy with the appearances on the Mississippi.

**Prof. James Hall also has mentioned the gneissic character of these rocks.

†Second annual report on the geological and natural history survey of Minnesota, p. 160, et sequens.

The region between the Sauk and St. Peter rivers affords no outcrops. It consists sometimes of thick forest and sometimes of rolling prairie, and has a wonderful number of lakes. The connection of the crystalline rocks north and south is, nevertheless, probable, if one bears in mind the general relations of the terrane. While the first plateau along the Mississippi, west from the supposed belt of Laurentian rocks, has an absolute hight above the ocean from 750 to 800 feet, and in the west the prairies of the Red river lie at an average elevation of 850 feet, the elevation over the sea of the table lands in the strike of the granite belt reaches 1,100 to 1,250 feet according to the levels of the engineers of the St. Paul and Pacific railroad.

Whittlesey and Norwood, assistants of Owen, more especially entrusted by him with the examination of the interior of Minnesota, have likewise assumed a belt of crystalline rocks which goes diagonally through Minnesota and is crossed by the Mississippi as well as by some of its tributaries. In this, Winchell also concurs, and has exhibited on his very hypothetical map a wide zone of granitic and metamorphic rocks in immediate connection with those in the northern part of the state.

So far as our present knowledge of the geological nature of the interior part of Minnesota extends, it can only be said of it that there are present all indications of the existence of an area of Laurentian rock, but that it appears in outcrop only in the shores of the larger streams, and is covered by a very heavy deposit of drift over almost its whole extent, and is thereby hid from geological examination. Also concerning the Huronian it is only permitted to presume as yet its existence on each side of the massive crystalline rocks. As the schists at Little Falls, on one side, can be so regarded, so Prof. James Hall classes the metamorphic sandstone and red quartzyte in southwestern Minnesota, which have there a great development, and also embrace the pipestone or catlinite layers, as equivalent to the Huronian in the neighborhood of lake Superior.

Equally valid also are all the Silurian boundaries which (as well as Devonian strata) Winchell represents on his map* in beautiful order west of the granitic and metamorphic zone. As Winchell himself remarks,** this supposition rests entirely and only on the fact that Prof. Hind, of the Canadian geological commission has exhibited on his map of the British possessions, north from Minnesota, similar portions of the Silurian and Devonian in belts running from north to south along the Red river, and that these extend to the 49th parallel of latitude, the boundary line of the United States.*

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*This map appears as a "preliminary geological map of Minnesota," with his first report.

** Pages 94 and 100, of the first report.

But they are ideal there also, inasmuch as the southern part of the Winnipeg district is covered, like the northwest part of Minnesota, by a heavy sheet of drift below which the deepest wells penetrate only into the clay shales of the Cretaceous formation. So far as I know, there is no instance of outcropping old rock along the Red river throughout its course in the United States, and the same is true of its course for sixty miles further northwest. It is true Owen mentions that he found an outcrop of limestone with Silurian fossils two to three feet above the level of the water, on the upper course of the Red river. I have, nevertheless, sought for this place in vain, and am strongly inclined to believe that the American geologist mistook a limestone boulder with fossils of the Trenton formation for outcropping rock *in situ.* The existence of a great thickness of transported drift in this region (an out-running portion of the Leaf Hills, which will be mentioned below,) makes this the more probable.† Should later investigations establish the correctness of Owen's statement, there would be reached then a long stopping-place in the progress of our knowledge concerning the structure of the earth's crust in this difficult portion of North America.

## THE CRETACEOUS FORMATION IN THE SAUK VALLEY.

At the village of Richmond on the Sauk river where the granitic and dioritic rocks of the Laurentian zone disappear entirely under the drift deposits, the river has cut a valley into the prairie the depth of thirty feet. In the steep banks I found strata of rock such that I had not as yet encountered in Minnesota, and which caused me to infer that I had here to do with strata of a younger formation. They are plastic clays of a prevailingly dark-blue color, with isolated lines of what appears to be white and yellow. Below the dark clays is a layer of kaolin with fragments of rock broken from the granite, and a few feet above the kaolin can be seen a band of very impure brown coal. The beds lie about horizontal, except that the kaolin layer has an entirely irregular outline, and presents to the beholder the appearance of a cloak-like covering of the underlying rock, which everywhere is granite as this appears in outcrop a short distance away.*

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*The report of Professor Hind on the Assiniboine and Saskatchewan district of British America appeared in 1849.

†This statement of Owen is on page 173 of his *Report of a geological survey*, etc. According to his description this spot lies 50 miles distant from Otter Tail lake, measured by the river, and hence ten to twelve miles above Breckenridge, the end of the St. Paul and Pacific railroad. On his map this place is given at least fifteen miles further up the river.

The river bluffs afford only scanty indications of the age of this formation. In spite of eager and continued search the plastic clays afforded me, besides several small fragments of shells, only a single small tooth of *Corax* or *Galeus*, which cannot be considered very reliable in determining the age of the beds. A few steps from the point at which these were found, shortly before my arrival, a shaft had been sunk, and in it a drill-hole carried further in hope of finding coal, which for several years has been reported in this region. By means of this mining work, though indifferently carried on, and by means of wells in the vicinity, have been discovered only some clay shales with impressions and fragments of fossils which show most conclusively that the beds which here lie directly on the granite belong to the Cretaceous formation, and indeed to the Benton group, or No. 2 of the series of the Missouri basin as it has been described by Meek and Hayden.** Not only are the bivalves, cephalopods, fish-teeth and scales identical, but the clays and shales are the same, at these distant points, and make it possible to establish an exact parallelism. Dark, plastic clays predominate. These alternate with fragile schists, with impure brown coal and clayey ironstone. The plasticity and the dark-blue to lead-gray color of these clays are so characteristic of the Benton group that they are distinguished easily from the sandy and marly portions as well as from the calcareous clayey beds of the upper members of the Missouri-Cretaceous.***

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*Winchell found later in several places on the St. Peter river, that a kaolin layer lies between the granite rocks and the clay beds, and sand deposits which here also are probably Cretaceous, (second annual report, 1874, p. 163, etc.) My observations upon the Cretaceous formation in Minnesota were first published in January, 1872, in Dana and Silliman's Journal of Science.

**Meek and Hayden's Palaeontological report of Lieutenant Warren's expedition to the Upper Missouri.

F. V. Hayden: On the Geology and Natural History of the Upper Missouri, in the Trans. Am. Phil. Soc., vol. xii, new series, part I.

***It is possible that the Fort Pierre group, only, could be confounded with it. This, however, holds a higher horizon, and likewise sometimes contains dark-colored plastic clays; but according to Meek and Hayden, the *Inoceramus problematicus* (= *In. labiatus* Schloth), the most abundant shell at Richmond, has not yet been afforded by these beds.

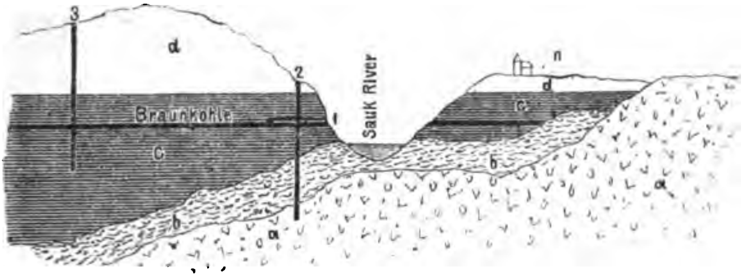
The above mentioned drill-hole, unfortunately, was made by men in whom all geological knowledge is wanting, and who neither kept a register of it nor were they in condition to give any reliable information concerning the nature of the layers penetrated. I was compelled, therefore, to depend on the material that had been piled up about the shaft.

The first search for coal was undertaken several years before by a farmer who had discovered the soft brown coal layer in the banks of the river. He ran a drift a distance of about sixty feet into the southerly bank, but a sudden rise of the water flooded his works and he then gave up the search.

The same farmer found coal three miles north from Richmond, in the midst of the forest, and dug three or four shafts in order to discover the supposed stratum. These also he was obliged to give up on account of the increasing waters. After that the matter remained unnoticed till 1870, when several merchants in St. Cloud rented the land in and around Richmond for the purpose of exploring for coal. There were sunk thereupon several shallow shafts in the neighborhood of the former experiment.

At the time of the experiment a streak of coal was said to have been followed of the thickness of four inches. The coal remained, nevertheless, very. impure, and consisted, indeed, for the greater part of bituminous shale, which even now can be seen in the little mound thrown up near the opening of the pit. The dip amounted to four feet over the whole distance of sixty feet, and hence for the whole clay-complex a slightly inclined position was shown of about four degrees toward the south. At the opening of the shaft could be seen blue, white and yellow plastic clays with a little gravel and much clay shale. The shale contains here some scales of cycloid fishes as well as many fragments of *Inoceramus* and *Ostrea*, but unfortunately not a single entire specimen of any determinable species. The adjoining profile shows the appearance of the Cretaceous beds at Richmond.

It is worthy of note, still, that in an old pit in the neighborhood of the trial pit small quantities of a very clear petroleum had gathered, and that the water of a brook in the neighborhood carried with it some petroleum.



a. Granit,
b. Kaolin,

*c.c.* Plastic clay and clay shale with a thin layer of impure brown coal.

*d.d.* Diluvium.

1. The above mentioned small test drift.
2. Shaft and drill of a hundred and twelve feet in which the granite was reached. The drill-hole entered the granite eight feet, and the auger brought up small pieces of feldspar, quartz and pyrites, apparently derived from a pegmatite like the same that I have met with frequently as viens in the granitic rocks of the region.
3. Shaft and drill a hundred and eighty feet deep in which the granite was not reached.

Afterward having learned that in the digging of wells at several farm-houses south from Richmond, fossils had been discovered, I set out on a search in that direction. On the surface nothing more can be seen of the easily distinguishable clays and clay-shales. The land is very rough, heavily wooded, and the sandy drift in some places very significantly disappears. Two miles south from the village I came to a farm-house where a well had raised to a high pitch the wonder of the whole region about. The well was dug thirty feet deep, and then by means of boring had been carried ten feet still deeper. At eight feet below the natural surface of the ground a dark plastic clay was encountered, which gradually changed to clay-shale with numerous large shells. The water of this well smelled strongly of sulphuretted hydrogen, but the odor was lost after it stood a little time in the air, and it was then used as drinking water. At that time I could obtain at the place only small fragments of shells, from which the clay shale had crumbled, and the valves had been broken. Of the relation of these fragments to *Inoceramus* but little doubt could be entertained. The well was soon afterward sunk somewhat deeper (always with the hope of encountering the coal stratum,) and the owner sent me several good specimens of the organic remains that were thus brought to light.

Besides the same fish-scales as on the Sauk river, were the valves of a large *Inoceramus* in great numbers, sometimes with the pearly interior perfectly preserved. Prof. Meek, at Washington, had the goodness to name these, and declared them to be the *Inoceramus problematicus* of the American geologists, adding further that this shell is identical with the *Inoceramus pseudomytiloëdes* which Dr. Schiel has figured in the second volume of the Pacific railroad reports, plate III, fig. 8.* I also got fragments and impressions of *Ammonites percarinatus*, Meek and Hayden, known from the Benton clays on the Missouri, very likely the same as *A. woolgari* Mant, and a *Scaphites* which Prof. Meek identified as his *Scaphites larvæformis*, or a closely related form of it, and which can scarcely be distinguished from *Scaphites æqualis* Sow.**

According to these fossils the clay and shale beds on the Sauk river correspond to the Lower Chalk, of England, the middle plains of Saxony, and the lower Turon of France (Turon Frankreichs).

According to the latest reports that have reached me, the well had been sunk, in a vain search for coal, still forty feet deeper, and that altogether it had reached the depth of 80 feet. The following statement shows the nature and thickness of the strata penetrated:

| | Feet. |
|---|---|
| 1. Gravel and sand | 8 |
| 2. Dark-blue, plastic clay, occasionally with a tendency to the form of shale; numerous valves of *Inoceramus problematicus* and crystals of gypsum | 30 |
| 3. Hard, sandy clay, and shale of lighter color, with pyrite, mica scales, and numerous scales of cycloid fishes. Fragments of *Inoceramus*. At the depth of forty feet a thin stratum of brown coal | 8 |

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*Probably this *Inoceramus* is identical with *Inoceramus mytiloëdes*, Mant. and *Inoc. labiatus*, Schloth. (Goldfuss. Petrefakta Germaniae, pl. II, p. 118. fig. 4.)

**At that time I sent the fossils and figures of the fragments which had crumbled, to the immortal professor Meek, at Washington, for determination. It has been impossible for me, however, to institute any later comparisons with European forms though the above determinations by so thorough a student of the Cretaceous formation of the interior of North America are sufficient to establish the horizon of the Minnesota beds and their full identity with the Fort Benton group on the Missouri.

| | | |
|---|---|---|
| 4. | The same clay with more layers of shale from three to four inches thick. Very large specimens of *Inoceramus problematicus*, as well as *Scaphites* and *Ammonites*. The valves sometimes retain their color and luster. At the depth of 50 feet a second thin bed of brown coal.... | 10 |
| 5. | Dark blue plastic clay without layering; the color still darker than the last thirty feet above, and sometimes entirely black. At the depth of 65 feet it was necessary to bore through a hard bed of grayish-black color....... | 15 |
| 6. | Clay, with thin scales and layers of pyrites........... | 10 |
| | Total........................................... | 81 |

The well was begun about 30 feet above the level of the water in Sauk river, and therefore at the same level as the prairie at Richmond, which shows the nearly level position of the strata. In a low meadow which in time of high water in the river, is connected with the river, I found the same unusual plastic clay at the surface. The locality where the above fossils were found lies two miles nearly south from Richmond, at the residence of a German farmer named Sieverding. The formation here certainly attains a very great thickness.

Besides the region about Richmond, I have also found the blue plastic clay on the shores of White Bear lake, in Pope county, [now Minnewashta lake—N. H. W.] at Glenwood, a village which lies 42 miles west from Richmond, and is 75 miles in a right line west from the Mississippi.* Here the clay appears under a covering of about two hundred feet of drift. This place is, therefore, the only positive evidence which I can cite for the extension of the Cretaceous beds towards the west, although I do not doubt such an extension, as will be further shown below; and hence, I believe it is correct to assume that these beds are continuous with the Missouri Cretaceous.

In the southern part of the state, Prof. Hall had ten years before described an impure, worthless bed of brown coal, which was associated with crumbling sandstone and sandy clays. In these beds appear leaves of dicotyledonous plants which point to an equivalence with the lower, or Dakota group, of the Missouri Cretaceous. They rest directly upon red-quartzytes which

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*White Bear lake is one of the most beautiful lakes in Minnesota. The water-level lies about 150 feet below the level of the surrounding prairie. The shores are steep and as usual are covered with great boulders which are derived from the sandy drift. The blue plastic clays come to light at a spot, a few feet above the surface of the water, where a spring gushes out of the bank whose clear water must have been gathered between the yellowish sandy loam and the blue clay.

Hall, as above mentioned, assigns to the Huronian formation. From Nobles county, on the border of Iowa, some years ago several fragments of *Baculites* were brought to St. Paul and were preserved in the collection of the Natural History Society. They were alleged to have been found in beds of clay several feet below the surface. In late years, N. H. Winchell has accurately described[*] as Cretaceous, the beds that are to be seen along the lower course of the St. Peters river, in southern Minnesota. Unfortunately he has found no fossils, except a few remains of leaves, and, therefore, the age of the sands, clays and marl-beds which lie on the Silurian rocks can be announced, as yet, only as conjectural. Not to mention that without the aid of fossils it would be difficult to decide whether a portion of these younger beds be not diluvial, yet, on account of the frequent appearance of an impure brown-coal, it is possible to suggest for them a Tertiary age, and to conceive them as contemporary with the beds which have been described by Hayden and Meek as the Great Lignite formation of the Missouri. Therefore it must remain for later research to furnish more light on this point.

Although all these localities are three hundred miles distant from the Missouri, the natural surface of the intervening region (the eastern part of Dakota territory and of western Minnesota) affords no objection to the supposition that the above-described Cretaceous beds and perhaps the still later brown-coal and sand are connected with the Cretaceous and Tertiary formations of the Missouri. There is no exposure of older strata, in this latitude, between the belt of Laurention rocks in the interior of Minnesota and the above formations on the Missouri. The several low hill ranges, the Leaf hills in Minnesota, and the Coteaux des prairie in Dakota, are nothing but great accumulations of sandy and stony drift. The Leaf hills, a succession of long ridges curved like a horseshoe, situated between the Red river and the sources of the Mississippi, I have crossed myself in several places, for the purpose of finding a suitable route for a railroad to the British possessions. Nowhere, not even in the deepest cuts, were any outcropping rock beds seen.

The southern sides of the hills are very steep while to the north their slopes are very gradual. The strongly marked terrane is in width from six to ten miles and is composed of long parallel ridges joined by smaller transverse ones. Boulders of various sizes of crystalline and sedimentary rocks lie scattered in wild confusion with numerous and very large erratic blocks.

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[*] First and second reports on the geological and natural history survey, 1873. 1874.

Personally, I did not visit the Coteaux of Dakota but every opportunity was embraced of becoming acquainted with it through the engineers and surveyors. I was assured that at least between the 45th and 47th degree of latitude, here considered, there was seen no outcrop of sedimentary rocks of any kind either along the water-courses or on the hillsides. This region, like the Leaf hills, appears to be made up of unstratified stony and sandy material.

Under this supposition both of these elevated ranges are of later origin than the deposits of Cretaceous age and were not present at the time when the almost completed level upland formed the bottom of the Cretaceous sea. For this reason there is less need of admitting the existence of a number of small Cretaceous seas and particularly since the discovered fossils are absolutely identical. The various divisions of the Cretaceous formation along the Missouri show in their thickest development a thickness of nearly two thousand feet and it is therefore probable that during Cretaceous times a large ocean covered the interior of the North American continent.

On the maps included in the works of Hayden and Meek, the eastern boundary of the Missouri-Cretaceous sea is not given and professor Meek has assured me that this is totally unknown. The formation disappears towards the east under the great diluvial covering.

So far as I am acquainted nothing has heretofore been discovered of the eastern extension of the Missouri-Cretaceous sea. It seems to me from the above information and observation that the conclusion will be granted that the described strata of Sauk river near Richmond formed a portion of the eastern shore line of the Missouri-Cretaceous sea; however, I do not wish it to be understood that this correlation is established as a positive fact.

## THE LOWER SILURIAN AND THE HURONIAN MELAPHYR OF THE ST. CROIX VALLEY.

The same difficulties met with in geological explorations west of the Mississippi Valley are also met with along our route through the state east of this great river until we reach the valley of the St. Croix. This river has its origin in the vicinity of the western arm of lake Superior and flows southerly towards the Mississippi and joins it after having formed the boundary line for 90 miles between the states of Minnesota and Wisconsin. In this entire distance the shores are covered with a dense primeval forest generally of pine, with a light sandy soil, while west of the Mississippi the forest is of deciduous trees and consists of oak, ash, maple, linden, walnut, etc., that grow in a heavy clayey soil. Only along the southern course of the St. Croix there extend sandy prairies interrupted by small forests of bur-oak to the vicinity of St. Paul.

Immediately after leaving the shores of the Mississippi on one side and the St. Croix on the other all possibility of geognostic observations on the surface are at an end. I have already stated that the first plateau of the Mississippi is from 750 to 800 feet above the ocean level. At this elevation the surface remains eastward from St. Paul to the St. Croix river. One rides for hours over rolling prairies and passes several large lakes in which the sandy and abundant diluvium with large erratic blocks cover all of the older sedimentary rocks. Suddenly the broad deeply eroded valley stretches out before the observer and a surprising view is given. With the greatest regularity several terraces rise one above the other and on the Wisconsin side at the same altitude can be readily followed as a step-like descent to the bottom of the valley.

The upper terraces are washed out of the diluvial formation; the lower ones lying partly in the Lower Silurian dolomyte, partly in the Potsdam or St. Croix sandstone which was formerly distinguished by American geologists as an older member of the Lower Silurian. Along the upper St. Croix are added the great eruptions of melaphyr and melaphyr-porphyry which form the base of the Silurian system in the vicintiy of lake Superior and which I shall have opportunity during this work to revert to more in detail.

* * * * On a geological map of Wisconsin published in the year 1869 by I. A. Lapham of Milwaukee, in place of these four formations [referring to Owen's map of 1851] there is but a single formation "trap," which branches from the southwestern point of the granitic and metamorphic rocks of Wisconsin. This comprehension is the proper one, as we shall see shortly that the crystalline rocks of the St. Croix are older than the Silurian sandstone. Similar formations of that which American geologists call "traprock" are found plentifully embedded in and on the edge of the Archæan

formation in Wisconsin, particularly in conjunction with quartzytes and conglomerates of Huronian age.

Owen regarded these rocks of the St. Croix as "porphyritic trap" and compared them with the Norwegian porphyry as found on the western side of Christiana-fjord at Bogstadt.* I also regarded it originally as a porphyry or a porphyry without quartz, under which name I first introduced it in 1871. Now, however. professor Streng found not only in the matrix of this rock but also in the porphyryritically disseminated crystals, besides the plagioclase only augite and its decomposition products (chlorite, or viridite and epidote) with very little orthoclase; and for this reason this rock is decidedly more basic than porphyrite, and should be rather placed with the melaphyrs†. The character of this rock upon the whole is nearly uniform; only in places are the porphyritic and amygdaloidal structures more abundant than in others. The matrix is cryptocrystalline and of a dark-green color; under a magnifier can be distinguished dark-brown to black banded feldspars and a transparent yellowish-green mineral, which has proved to be epidote, and probably was transformed from augite. Instead of placing it with the melaphyrs one could probably refer this rock of the St. Croix valley with equal correctness to diabase since the microscopic examination has shown both the constituents of diabase and the particular alteration peculiar to it, and further, that olivine and an amorphous matrix are totally wanting. Diabases of Huronian age south of lake Superior in Wisconsin and Michigan are besides of common occurence.

* * * * Besides Lingula and probably Obolus-valves I found in these Silurian strata only glabellas of trilobites the size of peas (*Conocephalus* cf. *minutus*). Of Lingula there is a form with a long pointed beak associated with much shorter and broader ones. Examples of the first attain a length of 15$^{mm}$. At first view one thinks he sees the well known *Lingula antiqua* and *Lingula prima* but of much larger size than those we are accustomed to meet with. The nature also of their association leads at once to the supposition that we have here the differently formed valves of but one and the same species. The large form with pointed beak Owen described as *Lingula pinnaformis*. His illustrations, however,

do not allow of its being distinguished from the *Lingula acuminata* Conrad[*] and in the description he does not point out the differences between it and the earlier described forms of the oldest Silurian. Later James Hall recognized the species *Lingula pinnaformis* Owen, noting, however, that the muscle impressions of all these valves, so far as he had observed, showed sufficient differences from true *Lingulae* to elevate the St. Croix form into a distinct genus and to which he gave the name *Lingulepis*[†]. At the same time he refers the shorter and broader form to *Lingulepis* but leaves it in doubt whether they belong to one or two species. Owen also cites from this locality *Lingula ampla* and *Orbicula prima*, both named by him, as well as *Lingula antiqua* and *prima* (?).

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*Owen's Geological Survey, page 161.

†Ueber die Krzstallinischen Gesteine von Minnesota, von A. Streng und J. H. Kloos. in *Leonhard's Jahrbuch*, 1877, pp. 49-51. [See translation of this in the Eleventh Annual Report. N. H. W.]

So far as the occurrence of all these species at St. Croix Falls is concerned it is positive that these identifications, as shown already by Hall,[‡] with *Lingula ampla*, rests partly on mistaking one thing for another and erroneous identifications. Owen's figures are too poor to admit of comparisons being made with other localities, and Hall, who had a large amount of material from St. Croix Falls at his disposition, admitted that he could not make out Owen's species.

The material which is at my command is unfortunately insufficient to thoroughly work out the fauna of this oldest Silurian stratum, and I am compelled in this to wait until I shall again have the opportunity of visiting these localities. Besides *Lingulepis pinnaformis* Owen, there can probably also be identified an *Obolus* which particularly occurs in the pyritiferous marl-slate, but also in the limestone layers associated with *Lingulepis*. Externally it very much resembles the *Obolus appolinis* Eichwald, of Russia, and it is only, upon the whole, larger, attaining a length and breadth of 11 $^{mm}$. The thin valves are irregularly concentrically striated and show an exfoliation of the outer layers, particularly towards the anterior edge, also a fine longitudinal lining. The greatest breadth lies somewhat below the middle, the lateral margins converge towards the beak and there form an angle of about 50°. On a single example only was it possible to uncover the muscular-impressions; they do not entirely agree with the drawings of *O. appolinis* as given by Davidson, in that the adductors instead of having an oblique direction and converging downwards towards the middle, are disposed in a straight line and stand perpendicular on the axis of the shell. With the small *Obolella* species from the Cambrian strata of England, the muscular impressions have also only a distant resemblance; agreeing no better with true *Lingulas* and with the illustrations of *Lingulepis.* It would be risky to found a new species upon this single example, and I prefer not to decide the question as to the proper disposition of those St. Croix brachiopods not belonging to *Lingulepis pinnaformis*[*]

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[*] From the Potsdam sandstone of Canada, compare Geolog. Report of Canada for 1864, p. 109.

[†] See Cont. to palæontology in the sixteenth Ann. Rep. of Regents of the University of New York. Appendix D. p. 129. Albany 1863. This work of the American palæontologist unfortunately came into my hands long after my visit to these localities

[‡] L. C., page 125.

## THE UPPER HURONIAN SLATES OF THE ST. LOUIS RIVER.

A third river which in central Minnesota demands the closest attention of the geologist is the one already named in the introduction, viz., the St. Louis river. It also offers for a great distance the only possibility of a view of the geognostic relations, Still more than on the St. Croix and on the upper Mississippi are here all explorations made more difficult, on account of the enormous forests and the extensive swamps. One reaches the St. Louis river now more easily by the railroad between St. Paul and lake Superior which was completed in the year 1869. This railroad follows at a small distance the course of the St. Croix and rises gradually from 700 feet at St. Paul to 1170 feet above the ocean level. Here it crosses the water-shed between the tributary streams of the Mississippi and those flowing in a northerly direction into lake Superior. This point is 120 miles distant from St. Paul and 35 miles from the western arm of lake Superior.

Outside of a few cuts in the Trenton limestone in the vicinity of St. Paul, the region along the Lake Superior railroad affords no exposures of the underlying rocks until one reaches the water-shed. Extended forests composed mainly of pines, firs, etc., stretch out on both sides. The country is flat and swampy, the brooks and water courses are cut but little into the surface. In the cedar-marshes, through which the railroad has been built on the hights of the water-shed, the first rocks project.

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[*] Although the material still in my possession is not sufficient to positively determine the proper relationship of the St. Croix river linguloid, yet the rich material at hand from other regions and in the Göttinger collection which my highly honored teacher professor Von Seebach, with the greatest willingness placed at my disposal, has assisted much to settle earlier wrongly-formed opinions, for which I should not neglect in this place to express publicly my thanks as well as for his general readiness to help and teach me.

They are steeply inclined, darkish slates whose stratified knobs are elevated but a few feet above the marsh. Where the railroad company has built a high bridge over the river in the vicinity of the new village Thompson, we there have the first opportunity to study more closely these slates. Here the water has broken through these steeply inclined slates and has formed over it a series of falls and rapids which in a few miles descend 370 feet and are known as the "rapids of the St. Louis river."

Particularly fine are the slates exposed in the railroad cuttings at the junction of the Lake Superior R. R. with the Northern Pacific. One can here follow the strike for a distance of half a mile without interruption as well as the dip of the strata which the slatiness proves with accuracy. The strike is nearly direct east and west, while the dip varies between 30° and 50° toward the south. Strata of a crystalline clay-slate alternate very regularly with a rock which on first view reminds one of many German grauwacke-slates such as one often meets with in the Kulms-grauwacke of the Upper-Hartz. This simply crypto-slaty rock I am now led, since the microscopic examination, to regard as a horn-slate.

The protrusions of the clay-slates are jagged and rough, while the intermediate layers, which in contrast with the clay-slates that have been wrought variously as roofing-slates, must be regarded as very imperfectly slaty, are smoothed off and more or less excavated in such a way that when one walks over the slate-complex perpendicular to the strike, the clay-slates form the ridges and the horn-slates the troughs. The thickness of the different strata is various; on the railroad I measured several clay-slate strata from 25 to 30 feet thick, while the intermediate beds of horn-slate are in general somewhat less in thickness. In other places however the thickness is considerably greater, and there are places where large quarries have been opened for the obtaining of roofing-slates. The transverse slatiness, which warrants this, passes through the entire clay-slate strata and shows in connection with the changeable dip of the strata a constant direction from 75° to 77° toward the south. Crevices filled with quartz, calcspar and feldspar are of common occurrence throughout the entire strata-complex.

For a long time uncertain where to place the rock here named horn-slate, I received my clue from a microscopic examination of it. A detailed description is therefore necessary. The color can be called a light green. This rock to the naked eye appears entirely compact although with many minute white and luminous dots which under a magnifying glass prove to be very small quartz and feldspar crystals, or grains, and which are imbedded in a felsitic matrix with a splintery fracture. Under the microscope there appears an irregular aggregation of quartz-grains and feldspar-crystals, and this is traversed in all directions by a dirty-greenish granular substance through which the whole receives the appearance of an irregular mesh or network. In quantity the quartz is predominant; the feldspars are prevailingly striated.

Where the green-colored substance is massed in somewhat greater quantities between the quartz and feldspar-crystals one can plainly observe that it shows no pleochroism between crossed nicols on rotating the preparation, as it remains totally dark. Under stronger magnification it dissolves itself into greenish, pipe-like bodies, flakes, pellicles and in still smaller, short, apparently colorless microliths, which however by turning the micrometer screw also become green and are therefore sections of flakes lying in the various strata of the preparation. Where the pipe like bodies, filled with a greenish pigment, lie between neighboring quartzes and feldspars, a parallel arrangement among them can be detected, and they are placed at right angles on the edges of the crystals. They also penetrate into the quartz and feldspar and sometimes completely fill the latter while the quartz usually appears clear and does not show many cavities or dark-edged bubbles. Rarely was I able also to discern moving bubbles. Yet the quartz could be sufficiently recognized by its clearness, smooth surface and active polarization. Magnetic iron appears in small, separated accumulations which by the strongest magnification dissolves only along the edges into small grains. The similarly formed particles of a dirty-brown color originate apparently from the decomposition of the magnetite.

We therefore have here an imperfectly slaty, crypto-crystalline rock composed of quartz, plagioclase, a greenish chloritic mineral and magnetite, with a sub-crystalline clay slate regularly interstratified, which agrees in its construction and nature with the horn-slates as it was recently described by R. Credner* from the older slate-formation of Saxony and which was formerly called felsyte-slate. This rock apparently was regarded by Norwood as well as by Eames as green stone. Its regular alternation with the roofing slate in thin beds but in a very thick and widely distributed slate-complex, points however decidedly against the acceptation that we have here to deal with a massive rock.

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*Compare G. R. Credner das Grünschiefer system von Hainichen im Kgr, Sachsen, in der Z. f. d. Ges. natur Wiss, 1876, B. XLVII, S. 25 ff.

For comparison with the horn-slate I also undertook a detailed microscopic examination of the roofing-slate. The following description is based on a thin section made parallel with the cleavage-planes. Only under strong magnification does this exceedingly fine-grained slate-rock resolve itself and then into the same greenish substance which to some extent forms the cement in the horn-slate between the quartz and feldspar crystals; only that in the roofing-slate it has a far greater share in the composition; one sees, besides this, but comparatively few sections of an anomalous nature which are first brought out by polarized light.

The pale-green substance is throughout not columnar and fibrous but chloritic and decidedly scaly; one distinctly recognizes the same flakes and pellicles as in the clay-slate and can observe how the flakes partly cover and are superimposed on one another. In polarized light they show no change but remain dark in turning the thin section between crossed-nicols. Of the larger sections there are two kinds: light, slightly colored and dark. Some of the light-colored ones give distinct evidence of mica scales. They polarize very lively, have a very irregular shape and are mostly fringed, also often creased and bent over on the edges. They are, however, to be regarded as clastic particles. All these nearly or altogether colorless sections cannot, however, be referred to mica, as a part of them appear to be quartz. The dark sections are sometimes almost square, occasionally rhomb-shaped and often wholly irregular in form. Their color appears in polarized light light-yellow, yet they are generally filled with a black untransparent substance which often causes them to appear as opaque particles. In direct light they appear in the dark field as faint yellow in color; in rare instances they attain the size of 0.1mm. the majority, however, remain below 0.01mm. in the largest section. The appearance signifies that these bodies are epidote.

Besides these larger sections one discerns, however, under a magnification of 400 diameters, still more numerous smaller needle-shaped forms which under crossed-nicols appear in the dark chloritic matrix as bright, shining, short threads. In turning the section they become light and dark and also exhibit faint colors; rarely do they attain a length of 0.5mm. with great thinness; generally, however, they are not over 0.005mm. long, and when compared to their length, somewhat broader. Magnetic-iron can be observed in somewhat large dust-like accumulations. Only with great effort, and after many failures, was it possible also to prepare a thin section transverse to the cleavage of the roofing-slates sufficiently thin and transparent to distinguish the various particles. This showed, first of all, that in contrast to the above observed mica- slates the slatiness is not dependent upon the position of the scales of a single element (in that case of the mica), but on the contrary that all particles have a stretched layering. With this there also appears a net-like stucture, in which the colorless, pellucid elements in parallel lentile-shaped aggregates are surrounded by a green chloritic substance. These now appear in transverse section between crossed nicols different from the picture presented in the longitudinal section. There is namely a polarization appreciable and at the same time a lamellar or fibrous structure in the sheets, parallel with the cleavage. These are shown plainest when the direction of the layers forms an angle of 45° with the principal sections of the nicol-prisms; when it coincides with one of the principal sections, the green scales appear totally dark. Thin splinters of the roofing-slate can with the aid of a blow-pipe be melted into a dark-green glass; the thinest splinters of the horn-slate, however, can only be rounded on the edges; after heating the pale green of the transparent edges of the splinters changes to an opaque brown-green. Muriatic acid had no effect upon the sections of the roofing-slate even after heating; powdered it was not appreciably affected by sulphuric acid.

After all this the difference between the horn-slates and the interbedded roofing-slates appears in the greater content of quartz and feldspar, while the latter contains more chloritic properties, and microlites the proper reference of which remains uncertain.

Midway between Thompson and Fond du Lac, a small village on the St. Louis river and up to which point this stream is navigable, the above slate system is uncomformably overlain by sandstone layers of the Lower Silurian. Lake Superior, as is known, forms a basin in these strata and repeats the same interrelations along the whole south shore*. Everywhere the Potsdam sandstone lies in undisturbed deposits upon the slate knolls of the great clay-chlorite-talk slates and quartzytes which together form the Huronian formation. Although I found no organic remains in the sandstone strata of the St. Louis river yet they undoubtedly belong to the Potsdam sandstone as one can conclude with reasonable certainty from analogy with its widely distributed and often repeated stratigraphic relations along lake Superior, and that these roofing and horn slates must be assigned to the Huronian.

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*Compare the above mentioned geological map of Wisconsin and H. Credner's: Vorsilurische Gebilde der "Oberen Halbinsel von Michigan" in der Zeit. der deut. geol-Gessel., 1869, pages 531 and 550.

A local disturbance of the inter-relations of the strata does not exist on the St. Louis river. The position of the slates of the older strata is similar, so far as opportunity to observe them has been afforded, everywhere in the regions of the Archæan slates. I also did not find in the vicinity any crystalline rocks to whose influence Norwood had earlier ascribed the position of the bedding, even though it may have been possible for him to give the direct proof of it. I do not doubt but that further examination of this portion of Minnesota will show a similar development of the Huronian system as that already described in detail for northern Michigan. * * *

## THE SILURIAN MELAPHYR AND GABBRO OF LAKE SUPERIOR.

The great clay masses already alluded to in the description of the diluvium which on lake Superior is distinguished by its prevailing red color, along the lower course of the St. Louis river conceal the older formations from the view of the observer. This certainly very young formation, which has never furnished organic remains, rises above the water level from 600 to 700 feet. It is on account of these deposits, that the relations between the Lower Silurian and the crystalline rocks cannot be determined and which on the western arm of lake Superior forms the shore.

At the terminus of the Lake Superior railroad near the steep cliffs where a few years ago the new city of Duluth originated, at several places these rocks are well exposed. They form almost the entire left shore of St. Louis bay and the bay of Superior. The former is a widening of the mouth of the river; the latter is formed by a narrow extension of the land separating a portion of the lake, and because of its protected position it forms a harbor much sought after.

The configuration of the western end of lake Superior is a most remarkable one. Narrow points branch off from the shore parallel with one another, and meet similar extensions from the opposite shore of Wisconsin. They still have between their extremities narrow openings affording entrance to the inner waters. The outer of these land extensions "Minnesota point" is six miles long and has a general width of only 600 feet. It consists of coarse pebbles (*shingle*) and is elevated but few feet above the water-level. The pebbles have a longish, flattened shape and consist mainly of melaphyrs and amygdaloids with larger and smaller calcspar amygdules, which one finds contiguous in the immediate vicinity.

Connor's point in Wisconsin and Rice's point in Minnesota divide St. Louis bay from the bay of Superior. Between them there is a 50 feet deep channel through which the waters of the St. Louis river flow into the lake. Superior bay has its greatest depth along the Minnesota shore. In Wisconsin the inhabitants had to build out into the bay several hundred feet to procure a depth of nine feet, while on the Minnesota side the water has a depth of 15 to 18 feet. A street of Duluth now follows along Minnesota point; the railroad company has cut the same near its junction with the land and has made an artificial water-way protected by a strong breakwater. The natural entrance six miles farther south is variously exposed to filling up with sand; this entrance is being continually improved by the inhabitants of Wisconsin and more particularly by the city of Superior, a competitor with the new town Duluth.

In the cliffs near the city of Duluth at the time of my visit, the soil and red clay had been removed in places by the building of streets. There appear essentially two totally unlike crystalline rocks. One of these, which was particularly well exposed at the railroad depot, I have already given in my first notice of Minnesota as a gabbroid or hypersthene rock. Since the examination by Prof. Streng it has actually proven to be gabbro; the preponderance of labrador-plagioclase with equal quantities of hornblende and diallage led him to regard it as hornblende-gabbro. Noticeable in this rock is the enormous wealth of feldspar and the great paucity of other elements, which are, except the titanic magnetic iron, difficult to detect between the feldspar-crystals and can only be distinguished with sufficient clearness in thin sections. The distinct twinning-striation, the plainly marked cleavage planes, the lustre and beautiful changeable colors, and the results obtained in the analysis of this rock all point to the labrador nature of the feldspar.

The pecular formation of this rock lends probability to the surmise that it is stratified—opposed to which, however, is the general distribution which it occupies on the cliffs along the St. Louis river. Unfortunately it was not possible to observe the contact relation with the other rock series. Its last appearance is several miles away from the Lower Silurian strata, and towards lake Superior the dense primeval forests conceal it from observation.

This rock, erroneously named Duluth granite, has recently found a common use in monumental work as it receives a very high polish.

A short distance beyond the gabbro (i. e. toward the east) the beautiful porphyry-like melaphyr forms the first rocky masses on the shore of lake Superior. In contrast with the gabbro above described is a green rock of similar composition, which forms on the St. Croix river the support of the Potsdam sandstone, and has here a prevailingly brown color and greater tendency to embrace amygdaloids. The latter are therefore on the western shore of the lake widely distributed and pass gradually into the compact rock. Under a magnifier one soon recognizes that the prevailingly brown muddy coloring is due to a profound separation of the individual elements, and the examination of a thin section shows particularly the feldspar to be impregnated with a granular substance which in the greatest magnification is no more definable. The presence of epidote, which mineral is secreted in various forms on the hills, and appears in conjunction with calcspar, laumontite, and a dusty iron-and-a-manganese-rich substance, as if impregnating the matrix of the melaphyr, points likewise to the change which the original elements have suffered.*

At one place only was there a slight break in this rock, and there it seemed to appear fresher, having a dark green-to-black color. Here it appeared in connection with fine non-porphyritic melaphyr ; whereas the immediate passage into the brown, epidotic, melaphyr-porphyry, which has a much larger distribution, was not discernible.

In the amygdaloids, into which the brown melaphyr passes insensibly in several places, the decomposition of the matrix has gone on considerably further. The longish cavities are filled with quartz, calcspar, a chlorite-like mineral and the above mentioned dark, dusty substance. There are also long crevices attaining several inches in size which are filled with large calcspar leaves, laumontite and epidote. Of a filling of the amygdaloids and crevices with copper or salt of copper, as it occurs on the north and south shores of lake Superior in the trap-like rocks of the Huronian and the Lower Silurian. not a trace was discovered at Duluth.

Although it cannot with certainty be stated what relation the melaphyr and gabbro of Duluth have with the sedimentary rocks, yet where the above described formation appears on the St. Louis river, the succession appears to me to allow the conclusion that the shores of the western arm of lake Superior are made up of beds in the Potsdam sandstone. and that they probably consist of dike-like intrusions. From the descriptions of Owen, Whittlesey, and others, we know that trap-like rocks, *i. e.* melaphyrs, play a great part on the north shore of lake Superior, and that they appear partly in a conformable position with the strata of the Potsdam sandstone and partly as dykes.

A ridge continues along the northern shore, and is composed of crystalline slates and other Archæan rocks. It extends from four to six miles into the land, with its greatest elevation from 600 to 1,000 feet above the water level. From the crest of this ridge the rocks descend gradually towards lake Superior, and here lie against the Silurian strata with a southerly dip. A number of winding streams have their origin on this ridge, rapidly descending through the various massive and stratified rocks, affording numerous exposures of the relations of the often very complicated strata. Some of these by their indications of copper have obtained a certain notoriety, and are still regarded as rich in copper by many people; this is particularly so in the French and Knife River districts, which are also within the limits of Minnesota.

To similar intrusions the above mentioned land-projections, which extend in front of the St. Louis river in a manner similar to the low ground in front of the river-mouths of northern Germany, point; but here they have a totally different origin.

Whittlesey has set up the proposition that the trap-like rocks, which contain metallic copper, are of the age of the Potsdam sandstone, while those containing sulphides belong to the Huronian.* And also that the copper bearing dykes become barren as they pass from the "trap" into the sandstone. The first portion of this proposition if proven would be of great importance to Lake Superior copper mining, still I believe I am forced to doubt its general accuracy. The diabase-like melaphyr of the St. Croix river, which is older than the Potsdam sandstone, is numerously traversed by dikes, in which of course now and then occur sulphides. Constantly, however, I found with it also pure copper in soft leaves and segregations or in threads, thin sheets, even in wire and button-shaped masses.*

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*Whittlesey's Report of 1866, page 5.

On the other hand, a dike-rock from the horizon of the Potsdam sandstone of the Knife River district, about 30 miles east of Duluth, had, besides pyrite, only sulphuret of copper in slight segregations, without a trace of pure copper.

At most localities where Huronian or Silurian melaphyrs appear, traces of copper have been found in the crevice-fillings. On the surface of the melaphyr of the St. Croix river one often sees feldspar veins of but few inches thickness which become wider at greater depths. One of these veins which could be traced on the surface for several hundred feet had at a depth of twenty feet a thickness of nearly 2½ feet. The samples from this depth consisted of a much decomposed rock rich in feldspar and lime, traversed with pure copper and sulphurets, however, only in small segregations and not in sufficient quantities to undertake large trial workings.

The larger masses of pure copper which up to this time have occasionally been found in Minnesota, come from the boulder-strewn hills of the diluvium. I also met with them along the river beds of the St. Croix and the Kettle rivers, and also from the eastern portion of the city of St. Paul. As similar copper drift has been found much farther south, even in the state of Ohio, in the "drift formation" one is justified in looking for their origin in the vicinity of lake Superior, and it is certainly to be deplored, as still often happens, that such foundlings awaken an expectation of finding a great richness of copper in the vicinity.

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A short resumé of the results obtained and a condensed view of our present knowledge of the geognostic relations of Minnesota may conclude these observations.

Within the limits of this state there have been determined with accuracy : the Archæan series; the strata of the Lower Silurian and Middle Cretaceous ages. In the southern part of the state there can probably also be added the Upper Silurian strata, which, however, soon thin out and have as yet furnished no characteristic fossils.

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*Compare J. Kloos Geol. Notizen aus Minnesota, in der Z. d. deutschen geolg Gessel. 1871, page 445.

The Archæan group in the middle portion of the state is particularly represented by massive crystalline rocks, chiefly composed of non-hornblendic and hornblendic granites (syenite granites), diorites (augite diorytes) as well as melaphyr-like rocks. Upon these succeed the crystalline slates, namely mica-slates, horn-slates and chloritic slates, which are usually formed as roofing slates and in which gneiss is observably wanting or at least very inconspicuous. In the north the crystalline, massive and slaty rocks have a very large distribution, and there it can be shown that the sequence of the Laurentian and Huronian systems is analogous to that of Canada, Michigan and Wisconsin. The Archæan slates through lateral pressure are similarly elevated over great areas, as can be observed everywhere along the edges of the massive Laurentian. On the knolls of the younger Huronian, preponderateingly chloritic-slates, or on the diabase-like melaphyrs, which belong to the same age, lie in a horizontal position the Lower Silurian sandstone strata. The latter have a great distribution and join directly the strata of the same age in Wisconsin. They are similarly traversed there as in western Canada by melaphyrs; melaphyr out-pourings have also spread over them and now alternate with them while they are again traversed by copper-bearing dikes. As probable inclusions in the Potsdam sandstone can also be added the hornblende-gabbro of Duluth.

A rock with hardly less areal distribution than the Potsdam sandstone is the following member of the Silurian—the lower dolomyte of the Mississippi; it is a constant associate with the sandstone. Of far less importance, however, are the younger strata; as the disintegrating nature of the St. Peter sandstone has caused the disappearance of this as well as the superimposed destructible strata of the Trenton limestone over great areas in the central portion of the state, and it now appears in several separated regions. The Silurian strata apparently lie everywhere horizontal but have a slight dip which in the southern part of the state is southerly while beyond Mountain lake it is toward the north.

Above the Silurian the various formations are wanting up to the Cretaceous period, at least none have been seen up to this time. It appears, therefore, that this middle portion of the North American continent during this enormous time was elevated above the ocean surface. In the wide valleys of the

Mississippi and St. Peter rivers there can also be seen evidences of great erosion, and at St. Paul on both sides of the stream it is apparent in the vast accumulation of boulders composed almost entirely of Silurian limestone, how powerfully these strata have been affected.

First during Cretaceous times was the western portion of the state again covered by the sea, and it formed a portion of the great Cretaceous ocean whose deposits can be studied along the Missouri in the most complete manner. The eastern shore of this great salt-water basin lay within the present region of the Mississippi. Whether Tertiary deposits were present, and later have disappeared through erosion to a few outliers, is uncertain. The predominating clayey and sandy Cretaceous formations have at least again suffered great erosion.

Diluvial formations are represented in great thickness and cover the southern and middle portions of the state, making it very difficult to investigate the lower formations. These youngest deposits can be separated into two natural groups,—the clayey-marls and the sandy gravel diluvium; and, further, the latter covers the unstratified clay and marl beds where the two come together.

The diluvium determines the configuration of the ground and forms adjoining step-like successions of table lands. The largest and deepest river valleys penetrate the diluvium to the Silurian and Huronian strata; the majority of the water-courses, however, have cut down only to the clayey diluvial deposits. The massive rocks of the Archæan group in the vicinity of the Mississippi and in the valleys of the Sauk and St. Peter rivers project above the diluvial formation. These are also for the greater part removed from observation by the plateau like diluvial deposits and only in the presence of a higher plateau, which on the St. Peter and Mississippi rivers joins with that of the northern part of the state, give evidence of the existence of a tongue of Laurentian rock transversely traversing the state. The restricted hill ranges towering above the table-land consist mainly of accumulations of boulders and presumably had their origin in currents or by the action of later erosion. Of high interest are the hydrographic relations of the low watersheds separating the great river systems. The waters now flow from a central high plateau in three directions; it is, however, probable that the northerly direction of the western stream, the Red river of the North, was first given to it in recent times, and that at an earlier date all waters found an exit either towards the south through the Mississippi valley or easterly through the great lakes.

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## III. CHEMISTRY.

### REPORT OF PROFESSOR JAMES A. DODGE.

UNIVERSITY OF MINNESOTA,
Minneapolis, Nov. 30, 1891.

*Professor N. H. Winchell.*

DEAR SIR: I hereby submit to you, for publication in the report of the State Geological Survey, a copy of the results of the chemical analyses of minerals, etc., made for the survey by the Chemical Department of the University since the last report. .

#### CHEMICAL SERIES NO. 194.

A sample of black sand. Analysis by J. A. Dodge.

| | | | | |
|---|---|---|---|---|
| Silica, | $SiO_2$ | 5.19 | per | cent. |
| Alumina | $Al_2O_3$ | 2.95 | " | " |
| Lime | $CaO$ | traces | | |
| Magnesia | $MgO$ | .35 | " | " |
| Oxide of titanium | $Ti'O_2$ | 36.77 | " | " |
| Protoxide of iron | $FeO$ | 32.29 | " | " |
| Magnetic oxide of iron | $Fe_3O_4$ | 22.10 | " | " |
| Phosphorus | | none. | | |
| Sulphur | | none. | | |
| Chromium | | none. | | |
| Total | | 99.65 | | |

This sand was but little attracted by the magnet..

#### CHEMICAL SERIES NO. 195.

A sample of iron ore. Analysis by J. A. Dodge.

| | | | | |
|---|---|---|---|---|
| Metallic iron | | 47.07 | per | cent. |
| Phosphorus | | .09 | " | " |
| Oxide of titanium | $TiO_2$ | traces. | | |

#### CHEMICAL SERIES NO. 196.

[illegible] dark gray crystalline rock. Analysis by J. A Dodge.

| | | |
|---|---|---|
| [illegible] titanium | $TiO_2$ | none. |

#### CHEMICAL SERIES NO. 196'.

ld ore. Assayed by C. F. Sidener.

Silver, none.

### CHEMICAL SERIES NO. 197.

A hematite ore. Analysis by C. F. Sidener.

| | | |
|---|---|---|
| Silica | $SiO_2$ | 8.25 per cent. |
| Alumina | $Al_2O_3$ | traces. |
| Lime and magnesia | | traces. |
| Ferric oxide | $Fe_2O_3$ | 92.08 “ “ |
| Manganese | | none. |
| Titanium | | none. |
| Sulphur | | none. |
| Phosphorus | | .09 “ “ |
| Total | | 100.42 |

### CHEMICAL SERIES, NO. 198.

A sample of ore. Analysis by C. F. Sidener.

| | | |
|---|---|---|
| Silica, | $SiO_2$ | 39.70 per cent. |
| Arsenical pyrites | | 60.30 |

### CHEMICAL SERIES NO. 199.

A sample of kaolin. Analysis by C. F. Sidener.

| | | |
|---|---|---|
| Silica | $SiO_2$ | 63.64 per cent. |
| Alumina | $Al_2O_3$ | 24.95 “ “ |
| Ferric oxide | $Fe_2O_3$ | 4.90 “ “ |
| Lime | $CaO$ | 1.02 “ “ |
| Magnesia | $MgO$ | .20 “ “ |
| Soda | $Na_2O$ | .66 “ “ |
| Potassa | $K_2O$ | .31 “ “ |
| Water and organic matter | | 4.32 “ “ |
| Total | | 100.00 |

### CHEMICAL SERIES NO. 200.

A reputed ore of silver, from the "Silver Star Lode," near Cable, Wis., sent by Mr. F. L. McKusick, of Stillwater, Minn. Assay by J. A. Dodge.

| | |
|---|---|
| Gold | very slight traces. |
| Silver | none. |

### CHEMICAL SERIES NO. 201.

A sample of water from a deep well at Stillwater, Minnesota. Analysis by C. F. Sidener.

| | |
|---|---|
| Chlorine | 30420 parts per million. |
| Bromine | 240 “ “ “ |

Reduced to grains per gallon U. S.

| | |
|---|---|
| Chlorine | 1,774.4 grains. |
| Bromine | 14.0 “ |

### CHEMICAL SERIES NO. 202.

An olivinitic magnetite. Analysis by C. F. Sidener.

| | | | |
|---|---|---|---|
| Silica | $SiO_2$ | 11.39 | per cent. |
| Alumina | $Al_2O_3$ | traces. | |
| Magnetic oxide of iron | $Fe_3O_4$ | 85.55 | " " |
| Lime | $CaO$ | .22 | " " |
| Magnesia | $MgO$ | 3.44 | " " |
| Oxide of titanium | $TiO_2$ | none. | |
| Sulphur | | traces. | |
| Phosphorus | | .02 | " " |
| Total | | 100.62 | |

### CHEMICAL SERIES NO. 203.

A titaniferous magnetite. Analysis by C. F. Sidener.

| | | | |
|---|---|---|---|
| Silica | $SiO_2$ | 11.37 | per cent. |
| Alumina | $Al_2O_3$ | 1.32 | " " |
| Magnetic oxide of iron | $Fe_3O_4$ | 53.33 | " " |
| Protoxide of iron | $FeO$ | 14.42 | " " |
| Oxide of titanium | $TiO_2$ | 16.03 | " " |
| Lime | $CaO$ | .10 | " " |
| Magnesia | $MgO$ | 2.73 | " " |
| Sulphur | | traces. | |
| Phosphorus | | .01 | " " |
| Total | | 99.31 | |

### CHEMICAL SERIES NO. 204.

A green siliceous rock. Analysis by C. F. Sidener.

| | | | |
|---|---|---|---|
| Silica | $SiO_2$ | 50.47 | per cent. |
| Alumina | $Al_2O_3$ | 18.48 | " " |
| Ferric oxide | $Fe_2O_3$ | 2.13 | " " |
| Ferrous oxide | $FeO$ | 7.74 | " " |
| Lime | $CaO$ | 6.61 | " " |
| Magnesia | $MgO$ | 6.90 | " " |
| Soda | $Na_2O$ | 2.58 | " " |
| Potassa | $K_2O$ | .30 | " " |
| Water | $H_2O$ | 2.34 | " " |
| Phosphorus | | traces. | |
| Total | | 97.52 | |

### CHEMICAL SERIES NO. 205.

A magnetic iron ore. Analysis by C. F. Sidener.

| | | | |
|---|---|---|---|
| Silica | $SiO_2$ | 11.85 | per cent. |
| Alumina | $Al_2O_3$ | .34 | " " |
| Magnetic oxide of iron | $Fe_3O_4$ | 87.00 | " " |
| Lime | CaO | .20 | " " |
| Magnesia | MgO | .80 | " " |
| Oxide of titanium | $TiO_2$ | none. | " " |
| Sulphur | | traces. | " " |
| Phosphorus | | .056 | " " |
| | | | " " |
| Total | | 100.246 | " " |

### CHEMICAL SERIES NO. 206.

A limonite ore. Analysis by C. F. Sidener.

| | | | |
|---|---|---|---|
| Silica | $SiO_2$ | 3.52 | per cent. |
| Ferric oxide | $Fe_2O_3$ | 87.10 | " " |
| Lime | CaO | traces. | " " |
| Magnesia | MgO | traces. | " " |
| Sulphur | | traces. | " " |
| Phosphorus | | .023 | " " |
| Water | $H_2O$ | 9.70 | " " |
| Total | | 100.343 | " " |

### CHEMICAL SERIES NO. 207.

A sample of borings from a well at Mankato, Minn., consisting mainly of magnetic oxide of iron. Analysis by C. F. Sidener.

Oxide of titanium.................. none.

### CHEMICAL SERIES NO. 208.

A sample of rock, showing black mica, feldspar and quartz, reputed to contain silver. Assay by J. A. Dodge.

Silver.............................. none.

### CHEMICAL SERIES NO. 209.

An iron ore. Analysis by C. F. Sidener.

| | | | |
|---|---|---|---|
| Silica | $SiO_2$ | 10.90 | per cent. |
| Alumina | $Al_2O_3$ | 5.83 | " " |
| Ferric oxide | $Fe_2O_3$ | 70,39 | " " |
| Ferrous oxide | FeO | 8.75 | " " |
| Lime | CaO | 1.20 | " " |
| Magnesia | MgO | 1.50 | " " |
| Sulphur | | .47 | " " |
| Phosphorus | | .022 | " " |
| Oxide of titanium | $TiO_2$ | none. | |
| Total | | 99.062 | " " |

### CHEMICAL SERIES NO. 210.

An iron ore. Analysis by C. F. Sidener.

| | | |
|---|---|---|
| Silica | $SiO_2$ | 3.62 per cent. |
| Alumina | $Al_2O_3$ | traces. |
| Ferric oxide | $Fe_2O_3$ | 95.76 " " |
| Lime | CaO | traces. |
| Magnesia | MgO | traces. |
| Sulphur | | none. |
| Phosphorus | | .093 " " |
| Total | | 99.473 |

### CHEMICAL SERIES NO. 211.

A siliceous material with a somewhat foliated appearance Analysis by J. A. Dodge.

| | | |
|---|---|---|
| Silica | $SiO_2$ | 60.05 per cent. |
| Alumina | $Al_2O_3$ | 27.55 " " |
| Ferric oxide | $Fe_2O_3$ | 1.30 " " |
| Lime | CaO | .38 " " |
| Magnesia | MgO | .77 " " |
| Soda | $Na_2O$ | .31 " " |
| Potassa | $K_2O$ | 4.26 " " |
| Phosphoric oxide | $P_2O_5$ | .11 " " |
| Water | $H_2O$ | 5.30 " " |
| Total | | 100.03 |

The material is to be regarded as a kaolin mixed with some undecomposed feldspar.

### CHEMICAL SERIES NO. 212.

A sample of quartz and pyrite. Assay by J. A. Dodge.

| | |
|---|---|
| Gold | traces. |
| Silver | none. |

### CHEMICAL SERIES NO. 213.

A sample of quartz and pyrite. Assay by C. F. Sidener

| | |
|---|---|
| Gold | none. |
| Silver | none. |

### CHEMICAL SERIES NO. 214.

A green mineral. Analysis by C. F. Sidener.

| | | | |
|---|---|---|---|
| Silica | $SiO_2$ | 43.96 | per cent. |
| Alumina | $Al_2O_3$ | 16.03 | " " |
| Ferric oxide | $Fe_2O_3$ | 10.50 | " " |
| Ferrous oxide | $FeO$ | 8.74 | " " |
| Lime | $CaO$ | 9.54 | " " |
| Magnesia | $MgO$ | 6.56 | " " |
| Soda | $Na_2O$ | 1.62 | " " |
| Potassa | $K_2O$ | .27 | " " |
| Water | $H_2O$ | 1.84 | " " |
| Total | | 99.06 | " " |

### CHEMICAL SERIES NO. 215.

A dolomitic rock. Analysis by C. F. Sidener.

| | | | |
|---|---|---|---|
| Silica | $SiO_2$ | 2.70 | per cent. |
| Alumina | $Al_2O_3$ | .35 | " " |
| Ferric oxide | $Fe_2O_3$ | 17.23 | " " |
| Ferrous oxide | $FeO$ | 8.35 | " " |
| Carbonate of lime | $CaCO_3$ | 49.80 | " " |
| Carbonate of magnesia | $MgCO_3$ | 19.65 | " " |
| Soda | $Na_2O$ | .20 | " " |
| Potassa | $K_2O$ | .04 | " " |
| Water | $H_2O$ | .47 | " " |
| Total | | 98.79 | " " |

### CHEMICAL SERIES NO. 216.

A sample of crystalline rock. Analysis by J. A. Dodge.

| | | | |
|---|---|---|---|
| Silica | $Si_2O$ | 67.42 | per cent. |
| Alumina | $Al_2O_3$ | 15.88 | " " |
| Ferric oxide | $Fe_2O_3$ | 1.37 | " " |
| Ferrous oxide | $FeO$ | 1.14 | " " |
| Manganese | | traces. | |
| Lime | $CaO$ | 3.49 | " " |
| Magnesia | $MgO$ | 1.43 | " " |
| Soda | $Na_2O$ | 6.42 | " " |
| Potassa | $K_2O$ | 2.65 | " " |
| Phosphoric oxide | $P_2O_5$ | .07 | " " |
| Oxide of titanium | $TiO_2$ | none. | |
| Water | $H_2O$ | .05 | " " |
| Total | | 99.92 | |

Very respectfully yours,
JAMES A. DODGE, Prof. Chemistry.

NOTE.—The foregoing substances were derived as follows:

*Chem. Series 194.*—Iron sand, fine, a few of the grains being magnetic. Birch lake beach, one mile west of the mouth of Dunka river.

*Chem. Series 195.*—Iron ore, Geol. Survey No. 1024, from J. Bausman's. Schistose ore, east of Garden lake.

*Chem. Series 196.*—Olivinitic ore, Geol. Sur. No. 976. From SW. ¼ Sec. 10, 62-12.

*Chem. Series 196'.*—Supposed gold ore 258 (H) submitted by H.V.W., Aug. 22, '87.

*Chem. Series 197.*—Iron ore, Prairie River Falls, Geol. Sur. No. 260 A. (H). Foot of the lower falls.

*Chem. Series 198.*—A heavy, white, metallic ore, said to have been found on White Iron lake. (Dovonan).

*Chem. Series 199.* —Kaolin, from near Brownsdale, Minn. From Mr. W. M. Jones, of C., St. P. & K. C. Ry.

*Chem. Series 200.*—Ore from Silver Star Lode, Cable, Wis. For F. L. McKusick, to compare with report of "Lehnen" in St. Paul.

*Chem. Series 201.*—Brine from the Stillwater deep weell.

*Chem. Series 202.*—Olivinitic magnetic, Geol. Sur. No. 408 (H). SE. ¼ Sec. 30, 62-10.

*Chem. Series 203.*—Titaniferous magnetic, Geol. Sur. No. 414 (H). SE. ¼, NE. ¼ Sec. 36, 63-10.

*Chem. Series 204.*—Green rock, Geol. Sur. No. 538 B. (H). Diabasic rock, ten feet from contact with jaspityte, SW. ¼, NW. ¼ Sec. 4, 63-9.

*Chem. Series 205.*—Magnetic iron ore, Geol. Sur. No. 369 A. (H). SW. side of Iron lake, NE. ¼ Sec. 23, 60-13.

*Chem. Series 206.*—Limonite, Geol. Sur. No. 354 (H). Mallmann's working, Sec. 29, 59-14.

*Chem. Series 207.*—Magnetic particles from the Mankato well, (at Minneopa). First rock below the red quartzite, (No. 10 of the section).

*Chem. Series 208.*—Sample of gneiss, from Auditor Braden. Said to have silver—so reported by "Lehnen," from his explorers on state lands in the northern part of the state.

*Chem Series 209.*—Magnetic iron ore, from the north side of Long lake, from the Vermilion series of rocks, Geol. Sur. No. 543 (H).

*Chem. Series 210.*—An amorphous hematite, from the Mesabi (Animikie) east of Grand Rrpids; the Warner-Griffin location.

*Chem. Series 211.*—White kaolinic "soapstone" Geol. Sur. No. 1449, stone mine.

*Chem. Series 212.*—Pyritifereous quartz, Eagle lake. Geol. Sur. No. 1501. Supposed to contain gold.

*Chem. Series 213.*—Pyritiferous quartz, and slate, supposed to represent the "gold ores" of Vermilion gold extitement in 1870. Geol. Sur. Nos. 395, 396, 397, 398, 400, 423, 428. All used as one sample.

*Chem. Series 214.*—Kawasachoug rock, Geol. Sur. No. 356.

*Chem. Series 215.*—Dolomitic or sodoric rock, from the Animikie, on Gunflint lake, Geol. Sur. No. 312.

*Chem. Series 216.*—Porphyritic conglomeritic rock, from Kekekebic lake, Geol Sur. No. ——? N. H. W.

# IV.—THE WOODS OF MINNESOTA.

By H. B. Ayres,

Agent of the Forestry Division, Department of Agriculture, Washington, D. C.

Among the natural stores so placed as to encourage the pioneer and develope the manly hardihood characteristic of the woodsman, the explorers of Minnesota found one of the grandest forests in one of the most accessible locations.

The conception first formed of the condition of the existing woodlands, is that all possible conditions are formed, and that they cannot be classified. Yet after the ceaseless variations have passed before the mind general classifications group themselves, and several portions of the wooded area stand out as having characteristics that distinguish them and separate the whole into groups. These groups are:

(1) The brush prairie bordering the first elevation above the plains on the south and west. The growth here is rose, hazel, thorn, plum, choke cherry, scrub oak, poplar, etc., with a stunted growth of the hardwood timber trees.

(2) The hardwood belt of oak, maple, basswood, elm, birch, poplar and ironwood on fertile undulating land dotted with lakes and broken by prairie openings. This land is now mostly in the hands of private owners, farmers, who are as a rule doing well.

(3) The jack pine and norway belt marking in general the border of a second elevation, a beach formation of sand and gravel, mostly non-agricultural, except in Hubbard Co., almost annually burned over, sparsely timbered, yet saved from denudation by the wonderful reproductive power of the scrub pine (P. banksiana), under shelter of which the norway pine (P. resinosa), develops rapidly into a valuable timber, and by the poplar under which the white pine is apt to start. This belt is well developed north west of Brainerd and no the east grades into the pine barrens of Wisconsin. It is frequently broken by areas of poplar and white birch, while much white pine exists here and there on the heavier soils.

(4) The white pine region, infinitely varied with hardwoods, norway and jack pine, cedar and tamarac swamps, and open or spruce bogs bordering the numerous lakes or occupying their old beds. In general, this region is brushy where not heavily

timbered, and so well watered with so little fall that but little white pine is more than five miles from drivable streams.

Nearly all of the streams of this region head in the open bogs, which, where partly shaded by spruce, make enormous growth of sponge-like spagnum moss holding the ice of winter until June and July and preserving a supply of water that the explorer may find under some upturned root, well into if not throughout the drought of August and September.

The soil here is usually loam or clay and supports a considerable growth of hardwood, among which the white pine reaches its most perfect development.

Much of this whole area has been stripped by fire even before the loggers increased the liability to fire by the tops they leave in the woods; and by the greater drying of the forest floor by exposure to sun and wind, in the openings they have made.

It has been estimated that thirty years ago over 40,000,000,000 feet of pine were standing on the 25,000,000 acres of forest in the state. Since that time busy milling towns have started up here and there as if by magic and loggers and choppers have swarmed into the forest until the average number of men now employed in preparing forest products for market reaches about 17,000, and the value of the product as placed upon the market amounts to about $2[illegible].

Must the industry soon decline?

The answer is a prompt and positive No.

If timber were a deposit like [illegible] power of reproduction [illegible] we could readily estimate the time [illegible] of the end.

In such a case we would see that with the present supply of standing timber—say [illegible] feet, [illegible] years more would see the state stripped.

But where fire is kept out [illegible] the [illegible] growth [illegible] woods [illegible] seedlings and [illegible] growth. The annual increment [illegible] feet [illegible] average about [illegible] cubic feet per acre per year, [illegible] of which should be estimated as one [illegible].

To produce an annual growth of [illegible] feet [illegible] the present annual cut—would at this rate require [illegible] acres.

In mournful contrast with these results obtained in Prussia, stands the estimate, though roughly made and presented with some hesitancy, yet approximating the fact, that the 24,960,000 acres of wooded area in the state did not, last year, grow more than 200,000,000 feet B. M. of log timber. In other words 50,000,000 acres of such forest as ours in its present condition would be required to grow the amount grown on 5,500,000 acres of well managed forest, and our forests are thus only producing less than one ninth of what they might.

We must not, however, forget that of the 24,960,000 acres now wooded, probably one-half will eventually prove more valuable as agricultural than as forest land, and suould be partly cleared. This would leave the area that should always be kept in forest, i. e. the lands unprofitable for agriculture as compared with forestry, about 12,500,000 acres, which, as above, should, under management, produce twice our present annual cut of log timber, and 400,000,000 cubic feet of other material for woodworking, fuel, etc.

Every considerable tract of forest in the state is more or less depleted by fire and can only be brought into full productlon after many years of renovation; but should any reader be tempted to cast these estimates aside as overdrawn, I must ask him to not do so without a careful study of the subject, such as I have given it during four years of exploring that have taken me all through the wooded region and formed in me a deep conviction that, while these estimates are necessarily rough, they are based on sound principles and at least point toward and approximate the truth.

Theoretically, therefore, it seems possible that the present yield of log timber alone may be doubled permanently and that a vast increase of manufacturing industries would follow the assurance of a constant supply, and, locating themselves throughout the woods, would in every way tend toward the greatest development of the state.

Practically, however, the difficulties in the way of attaining this ideal state of affairs are so great as to try the determination and skill of our best citizens.

The difficulties attending the question of ownership before operations of any kind can be commenced are the greatest that are to be met in the whole subject. In Europe, however, where claims of private owners were everywhere to be ajusted before anything could be done, this great barrier has been overcome satisfactorily to all.

In this country, where so much of the lower grade of agricultural land is owned by the government, there should be great hesitancy in making a beginning, beyond the caution necessary to make sure that the course be the right one.

In Europe the great difficulty has been just as here, the prejudice against anything but the free use of public property and against interference of the government in the business of individuals.

But they have, first in the moumtains where the general welfare most plainly demanded it, by condemnatory proceedings, and later, on the poorest lowlands, where the direct profits of forestry are greater than those of agriculture, by bounties to the owners of the land, made such progress during the past century that the wisdom of the movement is plainly shown, and all men who have the chance to know, combined with a desire for the public good, write in sustaining the governmental policy of securing the perpetual cultivation of forests on all the poorest lands.

## OUR LAND OFFICE SYSTEM.

While the giving of from 300,000 to 4,000.000 feet of standing pine to a poor pioneer seems a paternal act on the part of the government, the actual result is putting nearly all the value of the timber into the pocket of the lumberman, to whose plant the tract may be tributary.

The settler, even when honest, can, as a rule, afford to live on a pine claim merely long enough to comply with the homestead or pre-emption law, and when he sells his pine, often gives title to the land also, when it starts upon the routine by which it is, eventually, advertised for taxes, non-productive, idle, worthless.

If we continue, as we have done, the 17,000 men now employed in reaping the great natural harvest will soon leave the country, as they have left the older lumber states; for the lumberman, under the present system of disposing of public lands, cannot think of waiting for a second growth while he can acquire new forests of standing pine at a nominal figure. His only sensible course, as far as his own interests are concerned, is to strip off the timber and abandon the land.

The time to decide upon the use to which timbered lands should be put is, undoubtedly, before they pass into the hands of individuals. They should be examined and the question decided whether they should be thrown open for settlement as farm lands, or whether it would be best for the general welfare to have them kept in timber.

There are still in the state some 6,000,000 acres of more or less wooded land belonging to the federal government. To one looking the situation fairly in the face, would it not seem best to have all this area withheld from settlement until the soil be examined, and its adaptability determined?

The direct profits that may be expected from forestry, are not large after the virgin timber has been cut. In Europe, seldom over 5 per cent. is realized, and the American lumberman cannot be expected to act contrary to his notable common sense and shrewdness and stay and do a business that brings in 5 per cent., while he may by entering a new field, under the present land office system, get from 10 to 200 per cent. Only in exceptional cases, most favorable to growth and convenience to market, is forestry profitable to the individual. To a corporation of wood-workers the profits may be greater, but it is only the state or the general government that will be able to reap all those other benefits, such as permanency of industries, support of greatest population, etc., which, added to the direct profits possible to the individual, would bring the sum of gains well within the percentage of fair business profits.

Forest lands should therefore, as a rule, be managed by the state or by the federal government.

| | | |
|---|---|---|
| In Minnesota, the federal lands now vacant, and more or less wooded, amount to some | | 6,000,000 acres. |
| The state lands | 600,000 | |
| The university lands | 470,000 | |
| The school lands | 231,000 | |
| | | 1,301,000 |
| Total public forest lands | | 7,301,000 acres. |

The question as to what would be the best management of these lands has been studied and studied faithfully by many, if not by all the men upon whom their care devolved, and no doubt they have found the difficulties that they, single-handed, were unable to overcome. It is necessary that all the people be so well informed that they may, at least, be able to appreciate the efforts their chosen representatives in the local, state or federal government may make in their behalf; and while it is the plain duty of these representatives to study all the questions bearing upon the welfare of their constituent regions, these questions are so numerous that they cannot be expected to master them all, unless those who have made special study, aid them by digests of their work.

## FORESTRY IN PRUSSIA.

While some of the forestry that is practiced in Europe is for protection purposes on steep mountain slopes, where erosive torrents, destructive floods, landslides, falling rocks and avalanches make the work imperative, most of the forests there are managed for the revenues there are in them.

Some quotations from an article by Mr. Gillford Pinchot, before the American Economic Association, referring to forestry in Prussia, may be of interest here.

"All forest management may be said to rest on two closely related facts which are so self-evident that they might almost be called axioms of forestry, but which, like other axioms, lead to conclusions of far-reaching application. These are, first, that trees require many years to reach merchantable size; and, secondly, that a forest crop cannot be taken every year from the same land. From the last statement it follows that a definite, far-seeing plan is necessary for the rational management of any forest, from the first; that forest property is safest under the supervision of some imperishable guardian, or, in other words, of the State." * * * * * *

"Holding it as a duty to preserve the wood lands for the present share which they take in the economy of the nation, the State has recognized as well the obligation to hand down its forest wealth unimpaired to future generations. It has recognized and respected equally the place which the forest holds in relation to agriculture and in the economy of nature and hence feels itself doubly bound to protect its woodlands. In a word, it has been seen that in its direct and indirect influence the forest plays a most important part in the story of human progress, and that the advance of civilization only serves to make it more indispensable."

It has, therefore, steadily refused to deliver its forests to more or less speedy destruction by allowing them to pass into the hands of shorter lived and less provident owners

Even in the times of the greatest financial difficulty, when Prussia was overrun and nearly annihilated by the French, the idea of selling the State forests was never seriously entertained.

But the government of Prussia has not stopped here. Protection standing alone is irrational and incomplete. The cases where a forest reaches it highest usefulness by simply existing are rare. The immense capital which the State wood lands represent is not permitted to lie idle, and the forest, as a timber producer, has taken its place among the permanent features of the land. The government has done the only wise thing by managing its own forests through its own forest officers.

"Donner, now Overland first-meister, in a work which carries all the weight of an official document, says:

'The fundamental rules for the management of State forests are these: First, to keep rigidly within the bounds of conservative treatment; and secondly, to attain, consistently with such treatment, the greatest output of most useful products in the shortest time.' * * * * * * *

"The State believes itself bound, in the administration of its forests, to keep in view the common good of the people, and that as well with respect to the lasting satisfaction of the demand for timber and other forest produce, as to the numerous other purposes which the forest serves. It holds fast the duty to treat the government wood lands as a trust held for the nation as a whole, to the end that it may enjoy for the present the highest satisfaction of its needs for forest produce and the protection which the forest gives, and for all future time, at least an equal share of equal blessings." * * *

"The forest is a trust handed down from former times, whose value lies not only in its immediate production of wood, but also essentially in the benefit to agriculture of its immediate influence on climate, weather protections in various ways, the conservation of the soil, etc. The forest has significance not only for the present nor for its owner alone; it has significance as well for the future and for the whole of the people."

"With respect to the second class of forest property, that belonging to towns, villages and other public bodies, it is again impossible to speak for the whole of Germany except upon the broadest lines. The State everywhere exercises oversight and a degree of control over the management of these forests, but the sphere of its action varies within very wide limits. Even within the individual states it does not remain the same. Thus far, however, the action of the government is alike not only throughout Prussia but in all parts of Germany. It prevents absolutely the treatment of any forest of this class under im-provident or wasteful methods; nor does it allow any measure to be carried into effect which may deprive posterity of the enjoyment which it has a right to expect." * * *

The relations of the State to the third class of forests, those belonging to private proprietors, are of a much less intimate nature. The basis of these relations is, however, the same. To quote again from Donner: "The duty of the State to sustain and further the well being of its citizens regarded as an imperishable whole, implies for the government the right and the duty to subject the management of all forests to its inspection and control." This intervention is to be carried, however, "only so far as may be necessary to obviate the dangers which an unrestrained utilization of the forest by its owners threatens to excite, and the rights of property are to be respected to the utmost consistency with such a result." Prussia, of all the German countries, has respected these rights most highly, and the government exerts practically no restraining influence except where the evident results of deforestation would be seriously dangerous. Here it may and does guard most zealously the wood lands, whose presence is a necessary safeguard against certain of the more destructive phenomena of nature, and which have been called in general "protection forests". Of their many sided influence so much has been said and written of late in America—both truly and falsely—that no farther reference to the subject seems needful.

"The State leaves open a way of escape for the private proprietor who finds himself unwilling to suffer such restriction of his rights for the public good, and shows itself willing to buy up areas not only of protection forests but also of less vitally important wood lands. On the other hand, it is ready, with a broadness of view which the zeal of forest authorities sometimes unfortunately excludes, to give up to private ownership lands which, by reason of their soil and situation, will contribute better to the commonwealth under cultivation than as forest.

"In this way the forests whose preservation is most important are gradually passing into the hands of the State; yet the total area of the wood lands is increasing but slowly.

"The policy of State aid in the afforestation of waste lands important through their situation on high ground or otherwise is fully recognized (a notable example exists upon the Hohe Venn near Aix-la-Chapelle) but the absence of considerable mountain chains has given to this branch of government influence very much less prominence than in the Alps of Austria, Switzerland and France, where its advantages appear on a larger and more striking scale.

"In closing this brief sketch of forest policy in Prussia, you will perhaps allow me to refer for a moment to the erroneous ideas of German forest management which have crept into our literature. They have done so, I believe, partly through a desire of the advocates of forestry to prove too much, and they injure the cause of forestry, because they tend to make forest management ridiculous in the eyes of our citizens. The idea has risen that German methods are exaggeratedly artificial and complicated, and not unnaturally the inference has been made that forestry in itself is a thing for older and more densely populated countries, and that forest management is inapplicable and incapable of adaptation to the conditions under which we live. It is true, on the contrary, that the treatment of German forests is distinguished above all things by an elastic adaptability to circumstances, which is totally at variance with the iron-clad formality which a superficial observation may believe it sees. It is equally true that its methods could not be transported unchanged into our forests without entailing discouragement and failure, just as our method of lumbering would be disastrous there; but the principles which underlie not only German, but all rational forest management, are true all the world over. It was in accordance with them that the forests of British India were taken in hand and are now being successfully managed, but the methods into which the same principles have developed are as widely dissimilar as the countries in which they are being applied."

So forest management in America must be worked out along lines which the conditions of our life will prescribe. It never can be a technical imitation of that of any other country, and a knowledge of forestry abroad will be useful and necessary rather as matter for comparison than as a guide to be blindly obeyed. It must be suited not only to the peculiarities of our national character, but also to the climate, soil and timber of each locality, to the facilities for transportation, and relations of supply and demand, and the hundred other factors which go to make up the natural character of a hillside, a county or a state. Its details cannot be laid down *ex cathedra*, but must spring from a thorough acquaintance with the theory of forestry, combined with exhaustive knowledge of local conditions. It will necessarily lose the formality and minuteness which it has acquired in countries of older and denser settlement, and will take on the character of largness and efficiency which has placed the methods of American lumbermen, in their own sphere, far beyond all competitors.

## MUSEUM

SPECIMENS REGISTERED IN THE

| Serial No, | Obtained. | | Name. | Number of specimens |
|---|---|---|---|---|
| | When. | Whence. | | |
| 162 | Sept.. 1875 | Geol. Survey | Streptelasma corniculum Hall | 1 |
| 207 | 1875 | “ | Streptelasma corniculum Hall | 1 |
| 231 | Oct., 1875 | “ | Orthis testudinaria var. meeki Miller | 1 |
| 236 | Oct., 1875 | “ | Orthis testudinaria var. meeki Miller | 1 |
| 263 | Sept., 1875 | “ | Schizotreta pelopea Billings | 1 |
| 272 | Oct., 1875 | “ | Orthis testudinaria var. meeki Miller | Indef. |
| 273 | “ | “ | Orthis (Dinorthis) proavita W. and S. | 1 |
| 274 | “ | “ | Orthis (Dinorthis) subquadrata Hall | Indef. |
| 278 | “ | “ | Orthis (Dinorthis) proavita W. and S. | 2 |
| 279 | “ | “ | Orthis subæquata var. circularis Winchell | 3 |
| 294 | Sept., 1875 | “ | Climacograptus typicalis Hall | 1 |
| 295 | Sept., 1875 | “ | Climacograptus typicalis Hall | 1 |
| 302 | 1875 | “ | Diplograptus putillus Hall | 1 |
| 318 | Oct., 1875 | “ | Streptelasma corniculum Hall | 1 |
| 321 | Oct., 1875 | “ | Orthis subæquata Conrad | 2 |
| 346 | 1872 | “ | Orthis subæquata var. circularis Winchell | 3 |
| 364 | Oct., 1872 | “ | Streptelasma corniculum Hall | 1 |
| 390 | Oct., 1872 | “ | Climacograptus typicalis Hall | 1 |
| 396 | Oct., 1875 | “ | Orthis (Dinorthis) subquadrata Hall | 2 |
| 433 | Oct., 1875 | “ | Streptelasma profundum Hall | 2 |
| 651 | Aug. 1875 | “ | Orthis subæquata var conradi Winchell | 1 |
| 664 | Aug., 1877 | “ | Streptelasma profundum Hall | 1 |
| 672 | “ | “ | Orthis (Dinorthis) deflecta Conrad | 3 |
| 707 | “ | “ | Orthis (Dalmanella) subæquata Conrad | 3 |
| 710 | “ | “ | Streptelasma profundum Hall | 1 |
| 712 | “ | “ | Rauffella filosa Ulrich | 1 |
| 713 | “ | “ | Rauffella filosa Ulrich | 2 |
| 720 | “ | “ | Orthis (Dalmanella) subæquata Conrad | 2 |
| 734 | “ | “ | Rhynchonella ainsliei Winchell | 9 |
| 753 | “ | “ | Orthis subæquata var. conradi Winchell | 5 |
| 766 | “ | “ | Orthis (Dalmanella) subæquata Conrad | Indef. |
| 3487 | 1879 | “ | Streptelasma profundum Hall | “ |
| 3488 | 1879 | “ | Streptelasma profundum Hall | “ |
| 3489 | 1879 | “ | Streptelasma profundum Hall | “ |
| 3491 | 1879 | “ | Rauffella filosa Ulrich | 1 |
| 3493 | 1879 | “ | Rhynchonella capax Conrad | 2 |
| 3504 | May, 1879 | “ | Lingula cobourgensis Billings | 1 |
| 3513 | Aug., 1877 | “ | Orthis subæquata Conrad | 2 |
| 3515 | April, 1879 | “ | Orthis subæquata var. circularis Winchell | 2 |
| 4031 | Sept.. 1880 | “ | Rhynchonella ainsliei Winchell | 9 |
| 4032 | “ | “ | Orthis (Dalmanella) subæquata Conrad | Indef. |
| 4034 | “ | “ | Orthis tricenaria Conrad | 5 |
| 4035 | “ | “ | Orthis (Dalmanella) testudinaria Conrad | 2 |
| 4038 | “ | “ | Streptelasma profundum Hall | 1 |
| 4042 | “ | “ | Crania setigera Hall | 1 |
| 4049 | “ | “ | Orthis subæquata var. circularis Winchell | Indef. |
| 4053 | “ | “ | Rhynchonella capax Conrad | 1 |
| 4055 | “ | “ | Orthis (Dinorthis) meedsi W. and S | Indef. |
| 4056 | “ | “ | Orthis (Dalmanella) subæquata Conrad | “ |
| 4057 | “ | “ | Streptelasma profundum Hall | “ |
| 4061 | “ | “ | Rhaphistoma lenticularis Conrad | “ |
| 4076 | “ | “ | Orthis (Dinorthis) subquadrata Hall | “ |
| 4078 | “ | “ | Orthis testudinaria var. meeki | “ |
| 4079 | “ | “ | Orthis (Dinorthis) subquadrata Hall | “ |
| 4081 | “ | “ | Hindia sphæroidalis Duncan | 17 |
| 4085 | “ | “ | “ “ “ | 4 |
| 4092 | “ | “ | Rhynchonella capax Conrad | 6 |
| 4094 | “ | “ | Orthis (Plectorthis) whitfieldi Winchell | 1 |
| 4097 | “ | “ | Diplograptus putillus Hall | 1 |
| 4935 | 1882 | “ | Orthis subæquata var. circularis Winchell | 13 |
| 4944 | 1882 | Presented | Receptaculites oweni Hall | 3 |
| 4946 | 1882 | “ | Rauffella filosa Ulrich | 2 |
| 4948 | 1882 | “ | Platystrophia biforata Schlotheim | 1 |
| 4999 | 1882 | Geol. Survey | Rhynchonella capax Conrad | 10 |
| 5001 | 1882 | “ | Orthis (Dinorthis) pectinella var. sweeneyi Winchell. | 2 |
| 5053 | 1882 | Presented | Streptelasma profundum Hall | 6 |
| 5079 | 1876-1879 | Geol. Survey | Streptelasma profundum Hall. | 9 |
| 5148 | 1881 | Presented | Orthis subæquata var. perveta Conrad | 1 |
| 5149 | 1881 | “ | Orthis subæquata var. circularis Winchell | 1 |
| 5305 | Aug.. 1883 | “ | Streptelasma profundum Hall | 5 |
| 5307 | “ | “ | Platystrophia biforata Schlotheim | 1 |
| 5476 | Aug., 1877 | Geol. Survey | Rhynchonella capax Conrad | 9 |
| 5478 | “ | “ | “ “ “ | |
| 5479 | “ | “ | “ “ “ | 1 |

## ADDITIONS.

### GENERAL MUSEUM IN 1889, 1890 AND 1891.

| Locality. | Formation. | Collector and remarks. |
|---|---|---|
| Sec.17, Rochester, Olmsted Co., Minn. | Galena | M. W. Harrington (Garrick's quarry) |
| " " " " | " | " " |
| Spring Valley, Minn | Cincinnati | N. H. Winchell. |
| " " | " | " |
| Mantorville, Minn | Galena | M. W. Harrington. |
| Spring Valley, Minn | Cincinnati | N. H. Winchell. |
| " " | " | " |
| " " | " | " |
| " " | " | " |
| Minneapolis, Minn | Trenton | " |
| Mantorville, Minn | Galena | M. W. Harrington. |
| " " | " | |
| Forestville, Minn | Maquoketa? | N. H. Winchell. |
| Minneapolis, Minn | Trenton | " |
| " " | Hudson River | " |
| Rochester, Minn | Trenton | " |
| Near Rochester, Minn. | Galena | " |
| Mantorville, Minn | " | " |
| Spring Valley, Minn | Cincinnati | " |
| Chatfield, Minn | Trenton | " |
| Fountain, Minn | " | " |
| Pleasant Grove, Minn | " | " |
| Minneapolis, Minn | " | C. L. Herrick. |
| " " | " | " |
| " " | " | " |
| " " | " | " |
| " " | " | " |
| " " | " | " |
| " " | " | " |
| " " | " | " |
| " " | " | " |
| Near Cannon Falls, Minn | " | N. H. Winchell. |
| " " " | " | " |
| " " " | " | " |
| " " " | " | " |
| " " " | " | " |
| Minneapolis, Minn | " | H. V. Winchell. |
| " " | " | C. L. Herrick. |
| Oxford Mills, Goodhue county | " | N. H. Winchell. |
| Near Lanesboro, Minn | " | " |
| " " " | " | " |
| " " | " | " |
| " " | " | " |
| " " | " | " |
| Lanesboro, Minn | " | " |
| Near Fountain, Minn | " | " |
| " " " | " | " |
| " " " | Galena | " |
| " " " | " | " |
| " " " | Trenton | " |
| " " " | " | " |
| Spring Valley, Minn | Cincinnati | " |
| " " | " | " |
| " " | " | " |
| " " | Niagara | " |
| " " | " | " |
| " " | | " |
| " " | Cincinnati | " |
| " " | | " |
| State St., East Minneapolis | Hudson River | " |
| Near Marion, Minn | " " | Cora E. Goode |
| " " " | Trenton | " |
| " " " | " | " |
| Mineola, Goodhue county, Minn | " | N. H. Winchell. |
| " " " " | " | " |
| Minneapolis, Minn | " | H. V. Winchell. |
| " " | " | C. L. Herrick. |
| " " | " | J. C. Kassube. |
| " " | " | " |
| Cannon Falls, Minn | " | W. H. Scofield. |
| " " | " | " |
| Minneapolis, Minn | Green shale | C. L. Herrick. |
| " " | " | " |
| " " | " | " |

## MUSEUM

### SPECIMENS REGISTERED IN THE

| Serial No. | Obtained. | | Name. | Number of specimens |
|---|---|---|---|---|
| | When. | Whence. | | |
| 5480 | Aug., 1877 | Geol. Survey | Rhynchonella ainsliei Winchell | 31 |
| 5481 | “ | “ | Rhynchonella capax Conrad | 12 |
| 5483 | “ | “ | “ “ “ | 17 |
| 5484 | “ | “ | Rhynchonella ainsliei Winchell | 10 |
| 5485 | 1879 | “ | Rhynchonella capax Conrad | 4 |
| 5488 | 1879 | “ | “ “ “ | 14 |
| 5489 | 1879 | “ | Rhynchonella ainsliei Winchell | 3 |
| 5490 | 1879 | “ | Rhynchonella capax Conrad | 1 |
| 5491 | 1879 | “ | “ “ “ | 3 |
| 5492 | 1879 | “ | Rhynchonella ainsliei Winchell | 4 |
| 5493 | 1879 | “ | Rhynchonella capax Conrad | 6 |
| 5495 | Sept., 1880 | “ | “ “ “ | 2 |
| 5496 | “ | “ | “ “ “ | 3 |
| 5497 | “ | “ | “ “ “ | 3 |
| 5498 | “ | “ | Rhynchonella ainsliei Winchell | 1 |
| 5500 | “ | “ | Crania setigera Hall | 2 |
| 5505 | “ | “ | Rhynchonella ainsliei Winchell | 2 |
| 5506 | “ | “ | Rhynchonella capax Conrad | 1 |
| 5508 | “ | “ | “ “ “ | 12 |
| 5509 | “ | “ | “ “ “ | 4 |
| 5512 | “ | “ | Rhynchonella ainsliei Winchell | 3 |
| 5513 | “ | “ | Rhynchonella capax Conrad | 1 |
| 5515 | “ | “ | “ “ “ | 4 |
| 5516 | “ | “ | “ “ “ | 1 |
| 5517 | “ | “ | Rhynchonella ainsliei Winchell | 1 |
| 5518 | 1873 | “ | Rhynchonella capax Conrad | 2 |
| 5519 | 1880 | “ | “ “ “ | 5 |
| 5521 | 1880 | “ | Rhynchonella ainsliei Winchell | 1 |
| 5522 | 1880 | “ | Rhynchonella capax Conrad | 1 |
| 5547 | 1880 | “ | Rhynchonella perlamellosa Whitfield | 4 |
| 5548 | 1880 | “ | Platystrophia biforata var. crassa James | 1 |
| 5668 | 1884 | Purchase | Lingula elderi Whitfield | 1 |
| 5839 | May, 1885 | Geol. Survey | Ischadites iowensis Owen | 1 |
| 5840 | “ | “ | Streptelasma corniculum Hall | 9 |
| 5848 | “ | “ | Rhaphistoma lenticularis Sowerby | 7 |
| 5852 | “ | “ | Rhynchonella capax Conrad | 12 |
| 5856 | “ | “ | Orthis (Dalmanella) testudinaria | 2 |
| 5860 | “ | “ | Orthis meedsi W. and S | 4 |
| 5861 | “ | “ | “ “ “ | 2 |
| 5862 | “ | “ | Platystrophia biforata Schlotheim | 2 |
| 5865 | “ | “ | Cryptozoon minnesotense Winchell | Indef. |
| 6670 | Sept., 1885 | “ | Orthis remnicha Winchell | 7 |
| 6758 | June, 1888 | “ | Receptaculites oweni Hall | 1 |
| 6760 | “ | “ | Ischadites iowensis Owen | 3 |
| 6774 | Sept., 1888 | “ | Streptelasma profundum Hall | 1 |
| 6775 | “ | “ | Orthis (Dalmanella) subæquata Conrad | 1 |
| 6801 | “ | “ | “ “ “ “ | 2 |
| 6802 | “ | “ | Orthis tricenaria Conrad | 3 |
| 6803 | “ | “ | Orthis (Dalmanella) subæquata Conrad | 1 |
| 6804 | “ | “ | Orthis subæquata var. circularis Winchell | 2 |
| 6805 | “ | “ | Orthis | 7 |
| 6806 | “ | “ | Orthis (Dalmanella) testudinaria Dalman | 3 |
| 6808 | “ | “ | Streptelasma profundum Hall | 1 |
| 6828 | Jan., 1889 | “ | Rusted, coarse, quartz sand | Indef. |
| 6829 | “ | “ | Gray siliceous shale, or “slate”. | |
| 6830 | “ | “ | White sand, with some yellowish shale | |
| 6831 | “ | “ | Fine white sand, giving first water | |
| 6832 | “ | “ | Green shale | |
| 6833 | “ | “ | Fine white sand, with globules of pyrites | “ |
| 6834 | “ | “ | Green shale or sand, with some white sand | “ |
| 6835 | “ | “ | White sand with some specks of green sand | “ |
| 6836 | “ | “ | Mainly white sand, of a grayish aspect | “ |
| 6837 | “ | “ | Quartz sand, with some gray grains, all rounded | “ |
| 6838 | “ | “ | Rounded white sand, with some gray grains & pyrites | “ |
| 6839 | “ | “ | Gray shale, slightly greenish | “ |
| 6840 | “ | “ | White sand, with some fragments | “ |
| 6841 | “ | “ | White sand, rounded | “ |
| 6842 | “ | “ | Shale or clay, with quartz sand | “ |
| 6843 | “ | “ | Coarse quartz sand, almost pebbly | “ |
| 6844 | “ | “ | The same. Here the water all ran out | “ |
| 6845 | “ | “ | Red slate or shale, with white kaolinitic grains | “ |
| 6846 | “ | “ | White sand, with reddish grains and shale pieces | “ |
| 6847 | “ | “ | Red clay (shale) unwashed, hardened in drying | |
| 6848 | “ | “ | Dark red, or brown feldspathic sandstone | |

ADDITIONS.—*Continued.*

GENERAL MUSEUM IN 1889, 1890 AND 1891.

| Locality. | Formation. | Collector and remarks. |
|---|---|---|
| Minneapolis, Minn | Green shale | C. L. Herrick. |
| " " | " | " |
| Fountain, Minn. | " | N. H. Winchell. |
| Minneapolis, Minn | " | C. L. Herrick. |
| Near Cannon Falls, Minn | Hudson River | N. H. Winchell. |
| " " " | " | " |
| Minneapolis, Minn | Green shale | " |
| " " | " | " |
| " " | " | " |
| " " | " | " |
| " " | " | " |
| Near Lanesboro, Minn | " | " |
| " " " | " | " |
| " " " | " | " |
| " " " | " | " |
| Near Fountain, Minn | " | " |
| " " " | " | " |
| " " " | " | " |
| " " " | " | " |
| " " " | " | " |
| Minneapolis, Minn | " | " |
| Holden, Goodhue Co., Minn | " | " |
| Kenyon, Goodhue Co., Minn | " | " |
| Minneapolis, Minn | " | Chas. Kassube. |
| " " | " | " |
| " " | " | N. H. Winchell. |
| " " | " | H. V. Winchell. |
| Near Lanesboro, Minn | " | N. H. Winchell. |
| " " " | " | " |
| Spring Valley, Minn | Trenton | " |
| " " " | Cincinnati | " |
| Minneapolis, Minn | Trenton | Wm. Howling. |
| Cannon Falls, Minn | Galena | N. H. Winchell. |
| " " | " | " |
| " " | " | " |
| " " | Trenton | " |
| " " | Galena | " |
| " " | " | " |
| " " | " | " |
| " " | " | " |
| " " | Shakopee | " |
| Red Wing, Minn | | " |
| Holden, Minn | Galena | " |
| " " | " | " |
| Minneapolis, Minn | Trenton | " |
| " " | " | " |
| St. Paul, Minn | " | " |
| " " | " | " |
| " " | " | " |
| " " | " | " |
| " " | " | " |
| " " | " | " |
| " " | " | " |
| Stillwater, Minn | Drillings from Stillwater deep well. | N. H. Winchell, taken at 18 feet. |
| " " | | " " 103 " |
| " " | | " " 142 " |
| " " | " | " " 162 " |
| " " | " | " " 203 " |
| " " | " | " " 215 " |
| " " | " | " " 271 " |
| " " | " | " " 302 " |
| " " | " | " " 312 " |
| " " | " | " " 322 " |
| " " | " | " " 349 " |
| " " | " | " " 380 " |
| " " | " | " " 450 " |
| " " | " | " " 460 " |
| " " | " | " " 540 " |
| " " | " | " " 630 " |
| " " | " | " " 688 " |
| " " | " | " " 701 " |
| " " | " | " " 706 " |
| " " | " | " " 717 " |
| " " | " | " " 796 " |

## MUSEUM

### SPECIMENS REGISTERED IN THE

| Serial No. | Obtained. | | Name. | Number of specimens |
|---|---|---|---|---|
| | When. | Whence. | | |
| 6849 | Jany., 1889 | Geol. Survey | Dark red, or brown feldspathic sandrock | Indef. |
| 6850 | " | " | Somewhat darker, otherwise same as last. | " |
| 6851 | " | " | Same as last. | " |
| 6852 | " | " | Same as last. | " |
| 6870 | April, 1889 | Presented | Gold bearing quartz | 4 |
| 6871 | " | " | " " " | 3 |
| 6872 | " | " | " " " | 2 |
| 6873 | " | " | " " " | 2 |
| 6874 | " | " | Granite containing garnets | 1 |
| 6875 | " | " | Potsdam sandstone. | 1 |
| 6876 | " | " | "Cosmic material". | 4 |
| 6877 | " | Geol. Survey | Selenite. | Indef. |
| 6879 | June, 1889 | " | Yellowish blue pebbly clay | " |
| 6880 | " | " | Slightly darker pebbly clay | " |
| 6881 | " | " | Same as 6880. | " |
| 6882 | " | " | " " | " |
| 6883 | " | " | " " | " |
| 6884 | " | " | " " | " |
| 6885 | " | " | Gravel and sand bearing gas | " |
| 6886 | " | " | Same as 6880, pebbly clay | " |
| 6887 | " | " | " " " " | " |
| 6888 | " | " | " " " " | " |
| 6889 | " | " | " " " " | " |
| 6890 | " | " | " " " " | " |
| 6891 | " | " | Drift gravel and sand with fragments of lignite | " |
| 6892 | " | " | Drift gravel & sand with fragments of gray limestone. | " |
| 6893 | " | " | Fine quicksand. | " |
| 6894 | " | " | Magnesian limestone. | " |
| 6895 | " | " | Magnesian limestone drillings | " |
| 6896 | " | " | Gray limestone. | " |
| 6897 | " | " | Same as last, but with some drift. | " |
| 6898 | " | " | Same as last. | " |
| 6899 | " | " | Coarse drift pebbles | " |
| 6900 | " | " | Dolomitic limestone | " |
| 6901 | " | " | Same as last, but nearly white | " |
| 6902 | " | " | Gray aluminous limestone | " |
| 6903 | " | " | Gray limestone | " |
| 6904 | " | " | " " | " |
| 6905 | " | " | " " | " |
| 6906 | " | " | " " | " |
| 6907 | " | " | " " | " |
| 6908 | " | " | Gray limestone, finely crystalline | " |
| 6909 | " | " | Gray limestone, with siliceous grains | " |
| 6910 | " | " | Gray limestone. | " |
| 6911 | " | " | " " | " |
| 6912 | " | " | " " | " |
| 6913 | " | " | Gray shale, with quick effervescence | " |
| 6914 | " | " | Gray limestone. | " |
| 6915 | " | " | Bluish gray shale; slight effervescence | " |
| 6916 | " | " | Bluish gray shale; pebbly | " |
| 6917 | " | " | Fine bluish shale | " |
| 6918 | " | " | Coarser shale. | " |
| 6919 | " | " | Fine homogeneous gray shale. | " |
| 6920 | " | " | Blue and gray shale and limestone | " |
| 6921 | " | " | Same as last | " |
| 6922 | " | " | Fine bluish gray shale | " |
| 6923 | " | " | Blue shale. | " |
| 6924 | " | " | White sandstone | " |
| 6925 | " | " | " " | " |
| 6926 | " | " | " " | " |
| 6927 | " | " | White, fine sand | " |
| 6928 | " | " | Magnesian limestone | " |
| 6929 | " | " | White sandstone | " |
| 6930 | " | " | Magnesian limestone | " |
| 6931 | " | " | Mottled green and reddish shale. | " |
| 6932 | " | " | Green shale and magnesian limestone | " |
| 6933 | " | " | Mainly magnesian limestone | " |
| 6934 | " | " | Much like last, but more siliceous | " |
| 6935 | Aug., 1889 | " | Yellow loam, or clay | " |
| 6936 | " | " | Yellow clay—lacustrine | " |
| 6937 | " | " | Very fine lacustrine blue clay. | " |
| 6938 | " | " | Drift gravel with some clay | " |
| 6939 | " | " | Drift gravel, much limestone | " |
| 6940 | " | " | Coarse drift gravel, much limestone | " |

## ADDITIONS.—*Continued.*

### GENERAL MUSEUM IN 1889, 1890 AND 1891.

| Locality. | Formation. | Collector and remarks. |
|---|---|---|
| **Stillwater, Minn** | Drillings from Stillwater deep well. | N. H. Winchell, taken at 892 feet. |
| “ “ | | “ “ 923 “ |
| “ “ | | “ “ 952 “ |
| “ “ | “ | “ “ 2,250 “ |
| **Nova Scotia, Canada** | | Brookfield mine, Anderson, Douglas & Co. |
| “ “ | | Neptune mine, “ “ “ |
| “ “ | | Malaga district, “ “ “ |
| **Salmon River, N. S.** | | From Prof J. S. Clark. |
| “Garnet Hill” N. H. | | From Prof. J. A. Dodge. |
| Port Henry, N. Y. | Potsdam | From W. H. Benedict. |
| Nininger. Minn | ? | From Ig. Donnelly. |
| **Minneapolis, Minn** | | O. W. O. Contact of limestone and sandstone. |
| **Freeborn, Minn** | Drillings from Freeborn gas well. | No. 1. depth 20 feet. |
| “ “ | | “ 2, “ 30 “ |
| “ “ | | “ 3, “ 40 “ |
| “ “ | “ | “ 4, “ 50 “ |
| “ “ | “ | “ 5, “ 60 “ |
| “ “ | “ | “ 6, “ 70 “ |
| “ “ | “ | “ 7, “ 74 “ |
| “ “ | “ | “ 8, “ 80 “ |
| “ “ | “ | “ 9, “ 90 “ |
| “ “ | “ | “ 10, “ 100 “ |
| “ “ | “ | “ 11, “ 110 “ |
| “ “ | “ | “ 12, “ 120 “ |
| “ “ | “ | “ 13, “ 130 “ |
| “ “ | “ | “ 14, “ 140 “ |
| “ “ | “ | “ 15. “ 145 “ |
| “ “ | “ | “ 16, “ 150 “ |
| “ “ | “ | “ 17, “ 160 “ |
| “ “ | “ | “ 18, “ 190 “ |
| “ “ | “ | “ 19, “ 200 “ |
| “ “ | “ | “ 20, “ 210 “ |
| “ “ | “ | “ 21, “ 220 “ |
| “ “ | “ | “ 22, “ 230 “ |
| “ “ | “ | “ 23, “ 240 “ |
| “ “ | “ | “ 24, “ 250 “ |
| “ “ | “ | “ 25, “ 260 “ |
| “ “ | “ | “ 26, “ 270 “ |
| “ “ | “ | “ 27, “ 280 “ |
| “ “ | “ | “ 28, “ 290 “ |
| “ “ | “ | “ 29, “ 300 “ |
| “ “ | “ | “ 30, “ 310 “ |
| “ “ | “ | “ 31, “ 320 “ |
| “ “ | “ | “ 32, “ 330 “ |
| “ “ | “ | “ 33, “ 340 “ |
| “ “ | “ | “ 34, “ 350 “ |
| “ “ | “ | “ 35, “ 360 “ |
| “ “ | “ | “ 36, “ 370 “ |
| “ “ | “ | “ 37, “ 380 “ |
| “ “ | “ | “ 38, “ 390 “ |
| “ “ | “ | “ 39, “ 400 “ |
| “ “ | “ | “ 40, “ 410 “ |
| “ “ | “ | “ 41, “ 420 “ |
| “ “ | “ | “ 42, “ 430 “ |
| “ “ | “ | “ 43, “ 440 “ |
| “ “ | “ | “ 44, “ 450 “ |
| “ “ | “ | “ 45, “ 460 “ |
| “ “ | “ | “ 46, “ 470 “ |
| “ “ | “ | “ 47, “ 480 “ |
| “ “ | “ | “ 48, “ 490 “ |
| “ “ | “ | “ 52, “ 535 “ |
| “ “ | “ | “ 53, “ 710 “ |
| “ “ | “ | “ 54, “ 840 “ |
| “ “ | “ | “ 55, “ 880 “ |
| “ “ | “ | “ 56, “ 900 “ |
| “ “ | “ | “ 57, “ 920 “ |
| “ “ | “ | “ 58, “ 930 “ |
| “ “ | “ | “ 59, “ 950 “ |
| **Moorhead, Minn** | Drillings from Moorhead well. | “ 2, “ 5 “ |
| “ “ | | “ 3, “ 55 “ |
| “ “ | | “ 4, “ 110 “ |
| “ “ | “ | “ 5, “ 115 “ |
| “ “ | “ | “ 6, “ 125 “ |
| “ “ | “ | “ 7, “ 135 “ |

## MUSEUM

SPECIMENS REGISTERED IN THE

| Serial No. | Obtained. | | Name. | Number of specimens |
|---|---|---|---|---|
| | When. | Whence. | | |
| 6941 | Aug., 1889 | Geol. Survey | Drift gravel and sand | Indef. |
| 6942 | " | " | Sandy and gravelly clay | " |
| 6943 | " | " | Sandy clay—blue | " |
| 6944 | " | " | " " " | " |
| 6945 | " | " | Gravelly and sandy clay | " |
| 6946 | " | " | Boulder; hard gray gneiss | " |
| 6947 | " | " | Boulder; quartzose | " |
| 6948 | " | " | Bluish, sandy clay | " |
| 6949 | " | " | " " | " |
| 6950 | " | " | Quicksand | " |
| 6951 | " | " | Quicksand, with some clay | " |
| 6952 | " | " | Green shale or clay | " |
| 6953 | " | " | Soft reddish chlorite-granite or gneiss | " |
| 6954 | " | " | " " " | " |
| 6955 | " | " | " " " | " |
| 6956 | " | " | " " " | " |
| 6957 | " | " | " " " | " |
| 6958 | " | " | The same, but more like 6946 | " |
| 6959 | " | " | Same, but more green from chlorite | " |
| 6960 | " | " | " " " | " |
| 6961 | " | " | " " " | " |
| 6962 | " | " | Same, but finer | " |
| 6963 | " | " | Same, but coarser | " |
| 6964 | " | " | Same, but darker colored | " |
| 6965 | " | " | Same, fine drillings | " |
| 6966 | " | " | " " | " |
| 6967 | " | " | Soft, greenish, red-mottled felsyte | " |
| 6968 | " | " | Same, with some calcite | " |
| 6969 | " | " | Mainly water-worn sand | " |
| 6970 | " | " | Mixed granitic rock | " |
| 6971 | " | " | Mainly light chloritic granite | " |
| 6972 | " | " | Mostly white feldspar and quartz | " |
| 6973 | " | " | Brownish-red rock | " |
| 6974 | " | " | Gray, epidotic, finely granular gabbro | " |
| 6975 | " | " | Same as 6974 | " |
| 6976 | " | " | " | " |
| 6977 | " | " | Apparently the same, but finer | " |
| 6978 | " | " | Essentially quartzose | " |
| 6979 | " | " | Same as 6978; pyritiferous | " |
| 6980 | " | " | Drillings; gray, pulverulent | " |
| 6981 | " | " | Drillings brown, fine-grained | " |
| 6982 | " | " | Essentially a brown felsyte | " |
| 6983 | " | " | Conglomerate with brown felsyte | " |
| 6984 | " | " | Pink and gray conglomerate and quartzyte | " |
| 6985 | " | " | Granular white quartz | " |
| 6986 | " | " | Same, a granular quartzyte | " |
| 6987 | " | " | Same, but showing gray also | " |
| 6988 | " | " | Same, but more gray, also pink | " |
| 6989 | " | " | " " " " " | " |
| 6990 | " | " | Dark gray, pulverulent; similar to 6980 | " |
| 6991 | " | " | Trap-rock, epidotic diabase | " |
| 6992 | " | " | Gray diabasic trap-rock | " |
| 6993 | " | " | " " " | " |
| 6994 | " | " | Apparently the same, very fine | " |
| 6995 | " | " | Brown-gray diabasic rock | " |
| 6996 | " | " | Drillings of two sorts | " |
| 6997 | " | " | "Black slate" or argillyte | " |
| 6998 | " | " | " " " | " |
| 6999 | " | " | Same, but with a greenish tinge | " |
| 7000 | " | " | Same as 6998 | " |
| 7001 | " | " | Same as 6999 | " |
| 7002 | " | " | Essentially the same, not so slaty | " |
| 7003 | " | " | Same, rather light gray | " |
| 7004 | " | " | Gray slate, slightly pyritiferous | " |
| 7005 | " | " | " " " " | " |
| 7006 | " | " | Drillings of two kinds | " |
| 7007 | " | " | Drillings very fine, light yellowish | " |
| 7008 | " | " | " " " " " | " |
| 7009 | " | " | " " " " " | " |
| 7010 | " | " | Same as last, but also some of the next | " |
| 7011 | " | " | Gray, compact, fine, diabasic rock | " |
| 7012 | " | " | Same as 7011, with some gray slate | " |
| 7013 | " | " | Same as 7011 | " |
| 7014 | " | " | Same, gray rock predominates | " |

## ADDITIONS.—*Continued.*

### GENERAL MUSEUM IN 1889, 1890 AND 1891.

| Locality. | Formation. | Collector and remarks. |
|---|---|---|
| Moorhead, Minn. | Drillings from Moorhead well. | No. 8, Depth 145 feet. |
| " " | | " 9, " 155 " |
| " " | | " 10, " 165 " |
| " " | " | " 11, " 185 " |
| " " | " | " 12, " 195 " |
| " " | " | " 13, " 200 " |
| " " | " | " 14, " 220 " |
| " " | " | " 15, " 240 " |
| " " | " | " 16, " 300 " |
| " " | " | " 17, " 345 " |
| " " | " | " 18, " 360 " |
| " " | " | " 19, " 375 " |
| " " | " | " 21, " 400 " |
| " " | " | " 23, " 475 " |
| " " | " | " 24, " 600 " |
| " " | " | " 25, " 635 " |
| " " | " | " 26, " 745 " |
| " " | " | " 27, " 765 " |
| " " | " | " 28, " 800 " |
| " " | " | " 29, " 900 " |
| " " | " | " 30, " 1,000 " |
| " " | " | " 31. " 1,010 " |
| " " | " | " 32, " 1,050 " |
| " " | " | " 33, " 1.065 " |
| " " | " | " 34, " 1,090 " |
| " " | " | " 35, " 1,120 " |
| " " | " | " 36, " 1,195 " |
| " " | " | " 37. " 1,205 " |
| " " | " | " 38, " 1,265 " |
| " " | " | " 39, " 1,280 " |
| " " | " | " 40, " 1,325 " |
| " " | " | " 41, " 1,425 " |
| Duluth, Minn. | Drillings from Duluth deep well. | " 3, " 243 " |
| " " | | " 4, " 276 " |
| " " | | " 6, " 417 " |
| " " | " | " 7, " 448 " |
| " " | " | " 8, " 463 " |
| " " | " | " 9, " 468 " |
| " " | " | " 10, " 473 " |
| " " | " | " 11, " 490 " |
| " " | " | " 12, " 506 " |
| " " | " | " 13, " 508 " |
| " " | " | " 14, " 511 " |
| " " | " | " 15, " 513 " |
| " " | " | " 16, " 514 " |
| " " | " | " 17, " 516 " |
| " " | " | " 18, " 520 " |
| " " | " | " 19, " 524 " |
| " " | " | " 20, " 528 " |
| " " | " | " 21, " 530 " |
| " " | " | " 22, " 554 " |
| " " | " | " 23, " 574 " |
| " " | " | " 24, " 590 " |
| " " | " | " 25, " 598 " |
| " " | " | " 26, " 613 " |
| " " | " | " 27, " 619 " |
| " " | " | " 28, " 680 " |
| " " | " | " 29, " 880 " |
| " " | " | " 30, " 1,080 " |
| " " | " | " 32, " 1,175 " |
| " " | " | " 33, " 1,235 " |
| " " | " | " 34, " 1,340 " |
| " " | " | " 35, " 1,370 " |
| " " | " | " 36. " 1,375 " |
| " " | " | " 37, " 1,400 " |
| " " | " | " 38, " 1,435 " |
| " " | " | " 39, " 1,437 " |
| " " | " | " 40, " 1,445 " |
| " " | " | " 41, " 1,448 " |
| " " | " | " 42, " 1,450 " |
| " " | " | " 43, " 1,452 " |
| " " | " | " 44, " 1,454 " |
| " " | " | " 45, " 1,455 " |
| " " | " | " 46, " 1,456 " |

## MUSEUM

### SPECIMENS REGISTERED IN THE

| Serial No. | Obtained. | | Name. | Number of specimens |
|---|---|---|---|---|
| | When. | Whence. | | |
| 7015 | Aug., 1889 | Geol. Survey | Same, gray rock predominates | Indef. |
| 7016 | " | " | Same, but lighter colored | " |
| 7017 | " | " | " " " | " |
| 7018 | " | " | Gray quartzyte, very fine; same as 7014 | " |
| 7019 | " | " | " " " " | " |
| 7020 | " | " | Same, but more cleavable | " |
| 7021 | " | " | Same gray rock, slaty | " |
| 7022 | Jan'y, 1890 | Exchange | Spirifer pennatus Owen | 2 |
| 7023 | " | " | Spirifer keokuk var. | 3 |
| 7024 | " | " | Spirifer cameratus Morton | 2 |
| 7025 | " | " | Spirifer mucronatus Conrad | 5 |
| 7026 | " | " | Spirifer whitneyi Hall | 4 |
| 7027 | " | " | Spirifer hungerfordi Hall | 18 |
| 7028 | " | " | Spirifer orestes Hall and Whitfield | 3 |
| 7029 | " | " | Orthis impressa Hall | 7 |
| 7030 | " | " | Atrypa hystrix Hall | 2 |
| 7031 | " | " | Atrypa reticularis Linn | 13 |
| 7032 | " | " | " " " | 3 |
| 7033 | " | " | Atrypa aspera Schloth | 3 |
| 7034 | " | " | Rhynchonella alta Calvin | 10 |
| 7035 | " | " | Rhynchonella capax Conrad | 3 |
| 7036 | " | " | Athyris ambigua Sowerby | 6 |
| 7037 | " | " | Athyris subtilita Hall | 4 |
| 7038 | " | " | Productus costatus Sowerby | 3 |
| 7039 | " | " | Hemipronites crassus Meek and Worthen | 7 |
| 7061 | " | " | Zaphrentis spinulifera Hall | 1 |
| 7964 | " | " | Blue limestone | 1 |
| 7065 | Feb'y, 1890 | " | Apophyllite | 1 |
| 7066 | " | " | Iron, apophyllite and other minerals. | 1 |
| 7067 | " | " | Chacopyrite and pyrite | 1 |
| 7068 | " | " | Pyrite on calcite | 1 |
| 7069 | " | " | Magnetite (crystals) | 1 |
| 7070 | " | " | Calcite and apophyllite | 1 |
| 7071 | " | " | Byssolitic calcite | 1 |
| 7072 | " | " | Pink orthoclase | 1 |
| 7073 | " | " | Pyroxene | 1 |
| 7074 | " | " | Sphalerite | 1 |
| 7075 | Ma'ch, 1890 | Presented | Graphite | 1 |
| 7076 | " | " | Concretions in slate | 3 |
| 7077 | " | " | Kaoline | Indef. |
| 7078 | " | " | Lignite | " |
| 7079 | " | " | Asaphus canadensis Chapm | 2 |
| 7081 | 1876 | " | Fossil bones from S. America | Indef. |
| 7082 | June, 1890 | " | Pyroxenite var. "Websterite" 1st type | 1 |
| 7083 | " | " | Pyroxenite var. "Websterite" 2d type | 1 |
| 7084 | " | " | Coquina | 2 |
| 7085 | " | " | Asbestos, artificial | Indef. |
| 7086 | " | Exchange | Limestone, No. 1 | 2 |
| 7087 | " | " | " (above No. 1) No. 2 | 2 |
| 7088 | " | " | " No. 3 | 1 |
| 7089 | " | " | " No. 4 | 1 |
| 7090 | " | " | " | 1 |
| 7091 | " | " | " | 1 |
| 7092 | " | " | Marshall sandstone | 2 |
| 7093 | " | " | Limestone | 2 |
| 7094 | " | " | Conglomerate | 2 |
| 7095 | " | " | Green mica | 2 |
| 7096 | " | " | Feldspar | 1 |
| 7097 | " | " | Magnetite in granite | 7 |
| 7098 | " | " | Selenite | 8 |
| 7099 | " | " | Pyrite | 15 |
| 7100 | " | " | Calcite and pyrite | 6 |
| 7101 | " | " | Calcite | 12 |
| 7102 | " | " | Brown calcite crystals | 15 |
| 7103 | " | " | Stalactites | 8 |
| 7104 | " | " | Stalagmites | 3 |
| 7105 | " | " | Cyathophyllum | 7 |
| 7106 | " | Presented | Deposits from Mammoth Hot Springs | Indef. |
| 7107 | " | " | Limestone with barnacles attached | 3 |
| 7108 | " | " | Cinnabar | 1 |
| 7109 | " | " | Cinnabar crystals and some native quicksilver | 1 |
| 7110 | " | " | Vein rock with cinnabar | 1 |
| 7111 | " | " | Vein rock, barren (gangue) | 1 |
| 7112 | " | " | Foot wall rock (serpentine) | 1 |

## ADDITIONS.—*Continued.*

### GENERAL MUSEUM IN 1889, 1890 AND 1891.

| Locality. | Formation. | Collector and remarks. |
|---|---|---|
| Duluth, Minn | Drillings from Duluth deep well. | No. 47, Depth 1,457 feet. |
| " " | | " 48, " 1,468 " |
| " " | | " 49, " 1,477 " |
| " " | " | " 50, " 1,487 " |
| " " | " | " 51, " 1,495 " |
| " " | " | " 52, " 1,500 " |
| " " | " | " 53, " 1,507½ " |
| Independence, Iowa | Hamilton | C. W. Irish, Iowa City, Iowa. |
| Pella, Iowa | Sub. Carb | " " " |
| Madison Co., Iowa | Upper Carb | " " " |
| Widdler, Canada | Hamilton | " " " |
| Rockford, Iowa | Chemung | " " " |
| " " | " | " " " |
| " " | " | " " " |
| " " | " | " " " |
| " " | " | " " " |
| " " | " | " " " |
| Independence, Iowa | Hamilton | " " " |
| " " | " | " " " |
| Solon, Iowa | " | " " " |
| Fillmore Co., Minn | Trenton | " " " |
| Pella, Iowa | Sub. Carb | " " " |
| Madison Co., Iowa | Upper Carb | " " " |
| " " | " | " " " |
| " " | " | " " " |
| Pella, Iowa | Sub. Carb | " " " |
| Iowa City, Iowa | Hamilton | " " " |
| St. Peters, Chester Co., Pa | | J. Eyerman, Easton, Pa. |
| " " " | | " " " |
| " " " | | " " " [French Creek mines |
| " " " | | " " " |
| " " " | | " " " |
| " " " | | " " " |
| " " " | | " " " |
| " " " | | " " " |
| " " " | | " " " |
| Friedensville, Shegle Co., Pa | | " " " [Uberroth mine. |
| Town 64-6, S. E. ¼ Sec. 18 | | J. G. Emery. |
| Beaver Mine, Ont., Can | | J. W. Bist, 328 Oak st., Minneapolis. |
| Blaine Twp., Anoka Co | | H. V. Rumohe. |
| Big Fork, Ont., Can | | Stanley Newton, 12 miles bel. Big Falls, Big Fork |
| Fields Crossing, Ont | Utica slate | A. W. Vogdes (Georgian Bay.) |
| South America | | P. D. McMillan. |
| Balto Co., Md | | G. H. Williams. |
| " " | | " |
| St. Augustine, Fla | | Mrs N. H. Winchell. [Science Hall. |
| | | N. H. Winchell. (packing round steam pipes) |
| Grand Rapids, Mich | Sub. Carb | C. A Whittemore. |
| " " | " | " above No. 7086. |
| " " | " | " 2 feet deep. |
| " " | " | " 3 feet deep. |
| " " | " | " ½ mile N. E. of No. 7086. |
| " " | " | " showing penetration of iron oxide. |
| West of Grand Rapids, Mich | " | " above the limestone. [crystals. |
| Grand Rapids, Mich | " | " lining of cavity cells in place of |
| " " | Drift | " fossiliferous. |
| Brunswick, Maine | | " |
| " " | | " |
| Topsham, Maine | | " |
| Grand Rapids, Mich | | " |
| | | " |
| | | " Myrtle st. quarry. |
| Grand Rapids, Mich | | From C. A. Whittemore. |
| " " " | | " " |
| " " " | | " " 25 yrs. growth, cellar. |
| " " " | | " " " " " |
| " " " | | " " |
| Yellowstone Park | | J. B. Alexander. |
| Port Clinton, Puget Sound | | " |
| New Almaden, Cal. | | The Quicksilver Mining Company. |
| " " | | " " " |
| " " | | " " " |
| " " | | " " " |
| " " | | " " " |

## MUSEUM

### SPECIMENS REGISTERED IN THE

| Serial No | Obtained. When. | Obtained. Whence. | Name. | Number of specimens |
|---|---|---|---|---|
| 7113 | June, 1890 | Presented | Hanging wall rock (alta) | 1 |
| 7114 | " | Geol. Survey | Hinckley sandstone | 5 |
| 7115 | July, 1890 | " | Jaspilyte pebble | 1 |
| 7116 | " | " | Kidney iron ore | 1 |
| 7117 | " | " | Gray granite drillings | Indef. |
| 7118 | " | " | Pyrites | 1 |
| 7119 | " | " | Inyo marble (dolomite) | 1 |
| 7120 | Aug., 1890 | Exchange | Silicified wood | 1 |
| 7121 | " | " | Pectolite (massive) | 1 |
| 7122 | " | " | Garnet in mica schist | 1 |
| 7123 | " | " | Syenite | 1 |
| 7124 | " | " | Granite | 1 |
| 7125 | " | " | Garnet in mica schist | 1 |
| 7126 | " | " | White marble | 1 |
| 7127 | " | " | Trachyte | 1 |
| 7128 | " | " | Limestone | 1 |
| 7129 | " | " | Granite | 1 |
| 7130 | " | " | Chalcedony | 5 |
| 7131 | " | " | " | 1 |
| 7132 | " | " | " | 1 |
| 7133 | " | " | Colemanite (borate of lime) | 3 |
| 7134 | " | " | Sulphur (massive) | 1 |
| 7135 | " | " | Roscœlite (on quartz) | 1 |
| 7136 | " | " | Dye stuff, used for painting canoes and coloring tapa | 1 |
| 7137 | " | " | Chrysolite | Indef. |
| 7138 | " | " | Asbestos | " |
| 7139 | " | " | Ulexite (borate of lime) | 1 |
| 7140 | " | " | Volcanic ash or "White Lava" | 1 |
| 7141 | " | " | Syenitic granite | 1 |
| 7142 | " | " | Volcanic ash (indurated) | 2 |
| 7143 | " | " | Selenite | 2 |
| 7144 | " | " | Calcite | 1 |
| 7145 | " | " | Obsidian | 2 |
| 7146 | " | " | Halite | 1 |
| 7147 | " | " | Actinolite | 1 |
| 7148 | " | " | Feldspar | 1 |
| 7149 | " | " | Selenium (rare) | 1 |
| 7150 | " | " | Fuchsite | 1 |
| 7151 | " | " | Gneiss | 1 |
| 7152 | " | " | Colton marble | 1 |
| 7153 | " | " | Linarite (rare) | 3 |
| 7154 | " | " | Porphyritic diorite | 3 |
| 7155 | " | " | Gneiss, wall rock of Stonewall mine | 1 |
| 7156 | " | " | Core of diamond drill | 1 |
| 7157 | " | " | Quartz | 1 |
| 7158 | " | " | "Slickensides" | 1 |
| 7159 | " | " | Jasper | 4 |
| 7160 | " | " | Porphyry | 1 |
| 7161 | " | " | Hanging and foot wall of Nevada City mine | 1 |
| 7162 | " | " | Rock specimen, the deepest working of Comstock lode | 1 |
| 7163 | " | " | Syenite | 1 |
| 7164 | " | " | Steatite (soapstone) | 1 |
| 7165 | " | " | Diorite (used for paving) | 1 |
| 7166 | " | " | Ione red sandstone | 1 |
| 7167 | " | " | Granite | 1 |
| 7168 | " | " | Gold quartz | 1 |
| 7169 | " | " | Quartz and pyrite | 1 |
| 7170 | " | " | San Jose yellow sandstone | 1 |
| 7171 | " | " | Aragonite | 1 |
| 7172 | " | " | Wollastonite | 1 |
| 7173 | " | " | Altered serpentine and bronzite | 1 |
| 7174 | " | " | Gold quartz (Soulsby Mine) | 1 |
| 7175 | " | " | Halotrichite | Indef. |
| 7176 | " | " | Talcose slate, hard | 1 |
| 7177 | " | " | Hornblende | 1 |
| 7178 | " | " | Sample of foot and hanging wall rock | 1 |
| 7179 | " | " | Rock samples | 3 |
| 7180 | " | " | " | 1 |
| 7181 | " | " | " | 1 |
| 7182 | " | " | " | 2 |
| 7183 | " | " | " | 3 |
| 1784 | " | " | Foot wall of Nevada City Mine | 1 |
| 1785 | " | " | Stalactite (Clough's cave) | 8 |
| 1786 | " | " | Quartz with galenite and pyrite | 1 |

## ADDITIONS.—*Continued.*

### GENERAL MUSEUM IN 1889, 1890 AND 1891.

| Locality. | Formation. | Collector and remarks. |
|---|---|---|
| New Almaden, Cal | | The Quicksilver Mining Company. |
| Hinckley, Minn | | N. H. Winchell. |
| Arlington street, Minneapolis | Drift | N. H. Winchell. |
| " " " | " | N. H. Winchell. |
| LeMars, Iowa | | J. E. Todd, from near 1,400 feet down. |
| Near Porter, Minn | | J. F. Fries. |
| California | | California State Mining Bureau, No. 19 |
| Sonoma county, Cal | | " " " " " 21 |
| Tehama county, Cal | | " " " " " 22 |
| Stickeen River, Alaska | | " " " " " 23 |
| Kern county, Cal | | " " " " " 24 |
| Raymond, Fresno county, Cal | | " " " " " 25 |
| Reed Ranch, Marine county, Cal | | " " " " " 26 |
| Placer county, Cal | | " " " " " 27 |
| Waterloo Mt., Cal | | " " " " " 28 |
| Kern county, Cal | | " " " " " 29 |
| Oro Grand, San Bernardino Co., Cal. | | " " " " " 30 |
| Aurora, Nevada | | " " " " " 31 |
| Tuolumne county, Cal | | " " " " " 32 |
| Volcano, Amador county, Cal | | " " " " " 33 |
| Calico, San Bernardino, Co., Cal | | " " " " " 34 |
| Humboldt Co., Nev | | Cal.St.Min'g Bu., (Rabbit Hole mine) " 35 |
| California | | " " " 36 |
| Panipe Island, South Sea | | " " " 37 |
| Tuolumne Co., Cal | | " " " 38 |
| Shasta Co., Cal | | " " " 39 |
| Esmeralda Co., Nev | | " " " 40 |
| Volcano, Amador Co., Cal | | " " " 41 |
| Tuolumne Co., Cal | | " " ('country r'ck' ofSoulsby mn.) " 42 |
| Mokelumne Hill, Calaveras Co., Cal. | | " " " 43 |
| Monterey Co., Cal | | " " " 44 |
| San Bernardino Co., Cal | | " " " 45 |
| Glass Mt., Napa Co., Cal | | " " " 46 |
| San Bernardino Co., Cal | | " " " 47 |
| Sonoma Co., Cal | | " " " 48 |
| Mariposa Co., Cal | | " " " 49 |
| Honduras | | " " " 50 |
| Arch Bend, Orange Co., Cal | | " " " 51 |
| Humboldt Co., Cal | | " " " 52 |
| Colton, San Bernardino Co., Cal. | | " " " 53 |
| Cerro Gordo, Inyo Co., Cal | | " " " 54 |
| Shasta Co., Cal. | | " " " 55 |
| San Diego Co., Cal | | " " " 56 |
| Pica Cañon, Los Angeles Co., Cal | | " " (oil well No. 9) " 57 |
| Sheep Ranch, Tuolumne Co., Cal | | " " " 58 |
| San Bernardino Co., Cal | | " " " 59 |
| California | | " " " 60 |
| Calico, San Bernardino Co., Cal | | " " " 61 |
| Nevada Co., Cal | | " " " 62 |
| Virginia City, Nev | | " " " 63 |
| Point St. Pedro, Cal | | " " " 64 |
| El Dorado Co., Cal | | " " " 65 |
| California | | " " " 66 |
| Ione, Amador Co, Cal | | " " " 67 |
| Loomis, Placer county, Cal | | " " (Mtn. View mine) " 68 |
| Fresno county, Cal | | " " " 69 |
| Los Angeles county, Cal | | " " " 70 |
| California | | " " " 71 |
| Suisun, Solano county, Cal | | " " " 72 |
| Del Norte county, Cal. | | " " " 73 |
| Santa Clara county, Cal | | " " " 74 |
| Tuolumne county, Cal | | " " " 75 |
| Alameda county, Cal | | " " |
| Soulsbyville, Toulumne county, Cal. | | " " |
| Tuolumne county, Cal | | " " |
| Sonora, Toulumne county, Cal | | " " |
| San Bernardino county, Cal | | " " (Fenner) |
| Daggett, Cal | | " " |
| Near Poverty Hill | | " " |
| Colusa county, Cal | | " " |
| Providence, San Bernardino Co., Cal. | | " " |
| Nevada county, Cal. | | " " |
| Tulare county, Cal | | " " |
| Los Angeles county, Cal | | " " |

## MUSEUM

### SPECIMENS REGISTERED IN THE

| Serial No. | Obtained. |  | Name. | Number of specimens. |
|---|---|---|---|---|
|  | When. | Whence. |  |  |
| 7187 | Aug., 1890 | Exchange | Tourmaline schist | 1 |
| 7188 | " | " | Slate | 1 |
| 7189 | " | " | Trachyte | 1 |
| 7190 | " | " | Basalt (porphyritic) | 2 |
| 7191 | " | " | Quartz | 1 |
| 7192 | " | " | " | 3 |
| 7193 | " | " | Picrolite and serpentine | 1 |
| 7194 | " | " | Geysers | 3 |
| 7195 | " | " | Mariposite, "Blue Jay" | 1 |
| 7196 | " | " | Talcose rock | 1 |
| 7197 | " | " | Chalcedony | 4 |
| 7198 | " | " | Dike rock | 1 |
| 7199 | " | " | Contact between slate and greenstone | 1 |
| 7200 | " | " | Hanging wall, Amador Gold mine | 1 |
| 7201 | " | " | Wall rock in Washington mine | 1 |
| 7202 | " | " | Dike along "Mother Lode" | 2 |
| 7203 | " | " | "Diorite" | 1 |
| 7204 | " | " | Lava | 1 |
| 7205 | " | " | Rock specimens | 5 |
| 7206 | " | " | Agate | 1 |
| 7207 | Sept. 1890 | " | Borax crystals (artificial) | 1 |
| 7208 | " | " | Hanksite | 1 |
| 7209 | " | " | Ulexite (cotton balls) | 1 |
| 7210 | " | " | Borax crystals (tincal) | 1 |
| 7211 | " | " | Glauberite crystals | 6 |
| 7212 | " | " | Orthoclase crystals | 4 |
| 7213 | " | " | Borax crystals (tincal) | 5 |
| 7214 | " | " | Colemanite (borate of lime) | 1 |
| 7215 | " | " | Arsenopyrite (mispickel) | 1 |
| 7216 | " | " | Metallic antimony (native) | 1 |
| 7217 | " | " | Stibiconite | 1 |
| 7218 | " | " | Metacinnabarite | 1 |
| 7219 | " | " | Cinnabar | 1 |
| 7220 | " | " | " | 1 |
| 7221 | " | " | " | 1 |
| 7222 | " | " | " (in sandstone) | 1 |
| 7223 | " | " | Calymene mammillata Hall (and others) | 1 |
| 7224 | " | " | Murchisonia gracilis Hall (and others) | 2 |
| 7225 | " | " | Diplograptus peosta Hall | 4 |
| 7226 | " | " | Orthoceras sociale Hall | 16 |
| 7227 | " | " | Tentaculites sterlingensis Meek and Worthen | 2 |
| 7228 | " | " | Strophomena alternata Conrad | 2 |
| 7229 | " | " | Receptaculites | 1 |
| 7230 | " | " | Smithsonite | 1 |
| 7232 | " | " | Bythotrephis succulens Hall | 1 |
| 7233 | " | " | Sioux quartzyte | 2 |
| 7234 | " | " | Garnets in schist | 2 |
| 7335 | " | " | Hornblende schist | 1 |
| 7236 | " | " | Talc | 1 |
| 7237 | " | Presented | Garnets in mica schist | 1 |
| 7238 | " | Geol. Survey | "Winnipeg" limestone | 1 |
| 7239 | May, 1890 | Purchased | Meteoric stones | Indef. |
| 7240 | April, 1890 | " | Meteoric irons | 2 |
| 7241 | Aug., 1890 | " | Meteoric stones (chondritic) | 1 |
| 7242 | Sept., 1890 | Exchange | Pipe creek meteorite (chondrite) | 1 |
| 7243 | ........... | Presented | Quartz crystals | 1 |
| 7244 | 1891 | " | Magnetic iron ore | 1 |
| 7245 | 1891 | ................ | Staurolite | 1 |
| 7250 | Apr., 1891 | Geol. Survey | Ischadites iowensis Owen | 1 |
| 7251 | " | " | Receptaculites iowensis Hall | 1 |
| 7254 | " | Exchange | Trigonocarpon triloculare Hildreth | 14 |
| 7255 | " | " | Trigonocarpon hexacostatus | 1 |
| 7256 | " | " | " " | 1 |
| 7257 | " | " | Rhabdocarpon | 2 |
| 7259 | " | " | Parts of crinoid stems | .......... |
| 7260 | 1891 | " | Selenite | .......... |
| 7262 | 1891 | " | Phosphate rock: representing *redondite* | 1 |
| 7263 | 1891 | " | Phosphate rock: representing *redondite* | 1 |
| 7264 | 1891 | " | Phosphate rock: representing *redondite* | 5 |
| 7265 | 1891 | " | Phosphate rock representing *renondite* | 6 |

## ADDITIONS.—*Continued*

### GENERAL MUSEUM IN 1889, 1890 AND 1891.

| Locality. | Formation. | Collector and remarks. |
|---|---|---|
| San Benito county, Cal | | Calif. State Mining Bureau. |
| Calaveras, Cal | | “ “ “ |
| San Luis Obispo, Cal | | “ “ “ |
| Fresno county, Cal | | “ “ “ |
| Mt. St. Helena, Napa county, Cal | | “ “ “ |
| San Francisco, Cal | | “ “ “ |
| El Dorado county, Cal | | “ “ “ |
| Sonoma county, Cal | | “ “ “ |
| California | | “ “ “ (Mother Lode.) |
| “ | | “ “ “ |
| “ | | “ “ “ |
| “ | | “ “ “ |
| “ | | “ “ “ |
| South Jackson, Cal | | “ “ “ |
| California | | “ “ “ (Julian dists.) |
| Centerville, Cal | | “ “ “ |
| Virginia, Nev | | “ “ “ (C and C Shaft.) |
| Silver Peak, Nev | | “ “ “ |
| Gila River, Ariz | | “ “ “ |
| Central America | | “ “ “ |
| San Bernardino county, Cal | | Henry G Hanks, San Francisco. No. 1 |
| “ “ | | “ “ “ 2 |
| Esmeralda county, Nev | | “ “ “ 3 |
| San Bernardino county, Cal | | “ “ “ 4 |
| “ “ | | “ “ “ 5 |
| Maiden, Mont | | “ “ “ 6 |
| Esmeralda county, Nev | | “ “ “ 7 |
| San Bernardino county, Cal | | “ “ “ 8 |
| Tulare county, Cal | | “ “ “ 9 |
| Kern county, Cal | | “ “ “ 10 |
| Lander county, Nev | | “ “ “ 11 |
| Lake county, Cal | | “ “ “ 12 |
| “ “ | | “ “ “ 13 |
| Sonoma county, Cal | | “ “ “ 14 |
| San Luis Obispo county, Cal | | “ “ “ 15 |
| Napa county, Cal | | “ “ “ 16 |
| Graf, Iowa | Trenton | F. W. Plapp, Dubuque, Iowa. |
| “ “ | “ | “ “ “ |
| “ “ | “ | “ “ “ |
| “ “ | Hudson River | “ “ “ |
| “ “ | “ “ | “ “ “ |
| Dubuque, Iowa | Trenton | “ “ “ |
| “ “ | Gelena | “ “ “ |
| “ “ | | “ “ “ |
| Grant county, Wis | Trenton | “ “ “ |
| Rowena, South Dak | | “ “ “ |
| Hanover, N. H | | “ “ “ |
| Olcott Falls, Vermont | | “ “ “ |
| Norwich, “ | | “ “ “ |
| Alaska | | A. L. Broughton. |
| Minneapolis, Minn | Drift | Prof. N. H. Winchell. |
| Winnebago county, Iowa | | N. H. and H. V. Winchell. Fell May 2, 1890. |
| Kiowa county, Kansas | | N. H. Winchell—See Am. Geol., Vol. V., p. 309. |
| Washington county, Kansas | | Fell June 25, 1890. [Y. Acad. Sci., 1889. } |
| Bandera county, Texas | | Dr. H. Hensoldt—See Vol. VIII, Trans., N. } |
| Tower, Minn | Keewatin | Capt. R. J. Williams, Breitung iron mine. |
| Cerro de Mercado. Mexico | | Rev. J. A. Wright. |
| Pike Rapids, Mississippi River | | |
| Wasioja, Dodge county Minn | Galena | N. H. Winchell. |
| “ “ “ | “ | “ |
| Youngstown, Ohio | Carbon | W. H, McGinnis. |
| “ “ | “ | “ |
| “ “ | “ | “ |
| “ “ | “ | “ |
| Ohio | | “ |
| Ellsworth township, Mahoning Co., O. | | “ (Crystals in claymatrix). |
| Island of Redonda, Caribbean Sea. | | O. H. Hitchcock—The very best-40 p ct. $P_2O_5$. For No.'s 7262-7271, see Bul. Geol. Soc. Amer. Vol. II, p. 6. |
| “ “ | | O. H. Hitchcock.—The compact light colored part is supposed to be nearly pure *Redondite*. |
| “ “ | | O. H. Hitchcock.—High grade:—Nearly 40 p ct. $P_2O_5$. |
| “ “ | | O. H. Hitchcock.—About 35 p ct $P_2O_5$. |

## MUSEUM

### SPECIMENS REGISTERED IN THE

| Serial No. | Obtained. |  | Name. | Number of specimens |
|---|---|---|---|---|
|  | When. | Whence, |  |  |
| 7266 | 1891 | Exchange | Phosphate rock: representing *redondite* | 5 |
| 7267 | " | " | " " " | 5 |
| 7268 | " | " | " " " | 1 |
| 7269 | " | " | Phosphate earth. " |  |
| 7270 | " | " | Volcanic tufa | 1 |
| 7271 | " | " | Lava | 1 |
| 7272 | " | " | Calcite | 1 |
| 7273 | " | " | " | 1 |
| 7274 | " | " | " | 1 |
| 7275 | " | " | Trigonocarpon | 4 |
| 7276 | " | " | " | 1 |
| 7277 | May, 1891 | Presented | Granitic gneiss | 1 |
| 7278 | 1890 | " | Iron slag | 1 |
| 7279 | Dec., 1891 | Geol. Survey | Philodops trentonensis var minor W. and S | 3 slabs. |
| 7280 | July, 1891 | " | Subulites elongatus Conrad | 7 |
| 7281 | " | " | Murchisonia tricarinata Hall | 2 |
| 7282 | " | " | Pleurotomaria subconica Hall | 8 |
| 7284 | " | " | Murchisonia helicteres Salter | 6 |
| 7289 | " | " | Raphistoma lenticularis Sowerby | 5 |
| 7290 | " | " | Raphistoma | 2 |
| 7291 | " | " | Maclurea | 6 |
| 7292 | " | " | Cyrtolites compressa Conrad | 4 |
| 7293 | " | " | Bucania (Tremanotus?) buelli Whitfield | 2 |
| 7294 | " | " | Bucania | 3 |
| 7295 | " | " | Bucania bidorsata Hall | 1 |
| 7296 | " | " | Bellerophon | 3 |
| 7297 | " | " | Bellerophon wisconsensis Whitfield | 4 |
| 7298 | " | " | Bellerophon bilobatus Sowerby | 25 |
| 7303 | " | " | Subulites elongatus Conrad | 1 |
| 7304 | " | " | Pleurotomaria subconica Hall | 1 |
| 7308 | " | " | Maclurea bigsbyi Hall | 1 |
| 7309 | " | " | Cyrtolites compressa Conrad | 1 |
| 7310 | " | " | Bellerophon wisconsenis Whitfield | 2 |
| 7311 | " | " | Bellerophon bilobatus Sowerby | 6 |
| 7312 | " | " | Maclurea | 1 |
| 7313 | " | " | Pleurotomaria subconica Hall | 3 |
| 7314 | " | " | Murchisonia tricarinata Hall | 3 |
| 7316 | " | " | Bellerophon wisconsensis Whitfield | 1 |
| 7317 | " | " | Bellerophon bilobatus Sowerby | 1 |
| 7318 | " | " | Bucania (Tremanatus?) | 2 |
| 7319 | " | " | " " | 1 |
| 7321 | " | " | Pleurotomaria subconica Hall | 4 |
| 7328 | " | " | Raphistoma lenticularis Sowerby | 4 |
| 7330 | " | " | Bellerophon bilobatus Sowerby | 1 |
| 7333 | " | " | Raphistoma lenticularis Sowerby | 5 |
| 7337 | Aug. 1891 | " | Murchisonia gracilis Hall | 19 |
| 7343 | July 1891 | " | Trochonema | 1 |
| 7344 | " | " | Murchisonia gracilis Hall | 3 |
| 7345 | Aug. 1891 | " | Murchisonia major Hall | 3 |
| 7346 | " | " | Bellerophon | 1 |
| 7347 | " | " | Trochonema | 4 |
| 7348 | " | " | Raphistoma lenticularis Sowerby | 2 |
| 7349 | " | " | Maclurea | 2 |
| 7351 | " | " | Bellerophon bilobatus Sowerby | 12 |
| 7352 | " | " | Bellerophon wisconsensis Whitfield | 1 |
| 7353 | " | " | Raphistoma lenticularis Sowerby | 1 |
| 7354 | July 1891 | " | Bellerophon bilobatus Sowerby | 26 |
| 7356 | " | " | Maclurea | 4 |
| 7357 | " | " | Trochonema | 1 |
| 7358 | " | " | Pleurotomaria subconica Hall | 2 |
| 7546 | " | " | Homotrypa seperata var. | 1 |
| 7547 | " | " | Philloporina reticulata Hall | 1 |
| 7548 | " | " | Rhinidictya fidelis Ulrich | 2 |
| 7549 | " | " | Rhinidictya trentonensis Ulrich | 3 |
| 7550 | " | " | Monotrypa | 5 |
| 7551 | " | " | Leptotrypa hexagonalis Ulrich | 1 |
| 7552 | " | " | Rhinidictya | 1 |
| 7553 | " | " | " | 1 |
| 7554 | " | " | Rhinidictya fidelis Ulrich | 1 |
| 7555 | " | " | Nicholsonella ponderosa | 1 |
| 7557 | " | " | Leptotrypa hexagonalis Ulrich | 1 |

## ADDITIONS.—*Continued.*

### GENERAL MUSEUM IN 1889, 1890 AND 1891.

| Locality. | Formation. | Collector and remarks. |
|---|---|---|
| Island of Redonda, Caribbean Sea | | C. H. Hitchcock.—About 27 p ct. $P_2O_5$. |
| “ “ | | “ About 24 p ct. $P_2O_5$. |
| “ “ | | “ Splendid grains or concretions. |
| “ “ | | “ About 12 p ct $P_2O_5$. |
| “ “ | | “ From tunnel in midst of workings. |
| “ “ | | “ |
| New Galilee, Beaver county, Pa | | H. W. Williams (Brown). |
| “ “ | | “ (White). |
| “ “ | | “ “ |
| Ohio | Carbon | H. W. Williamson. The Mt. Hope type of the country (nuts in matrix.) |
| “ | “ | “ (shell of the nut.) |
| | Taconic? | Frank L. Nason, rock of the N. J. magnetite mines. |
| Tribune fire, Minneapolis | | H. V. Winchell, resembles meteoric iron. |
| St. Paul, Minn | Trenton | C. Schuchert. |
| Janesville, Wis | “ | “ |
| “ | “ | “ |
| “ | “ | “ |
| “ | “ | “ |
| “ | “ | “ |
| “ | “ | “ |
| “ | “ | “ |
| “ | “ | “ |
| “ | “ | “ |
| “ | “ | “ |
| “ | “ | “ |
| “ | “ | “ |
| “ | “ | “ |
| “ | “ | “ |
| Beloit, Wis | “ | “ from C.&N.W.R.R.qry, 3½m. n. of Beloit. |
| “ | “ | “ |
| “ | “ | “ |
| “ | “ | “ |
| “ | “ | “ |
| “ | “ | “ |
| Rockton, Ill | “ | “ |
| “ | “ | “ |
| “ | “ | “ |
| “ | “ | “ |
| “ | “ | “ |
| “ | “ | “ |
| Beloit, Wis | “ | “ fr. Samp's qry. in the “Up. Buff Beds |
| “ | “ | “ |
| Neenah, Wis | Galena | “ |
| Oshkosh, Wis | “ | “ |
| “ | “ | “ |
| Graf, Iowa | Cincinnati | “ |
| Janesville, Wis | Trenton | “ |
| “ | “ | “ |
| Dubuque, Iowa | Galena | “ |
| “ | “ | “ |
| “ | “ | “ |
| “ | “ | “ |
| McGregor, Iowa | Trenton | “ |
| “ | “ | “ |
| “ | “ | “ |
| “ | “ | “ |
| Mineral Point. Wis | “ | “ |
| “ | “ | “ |
| “ | “ | “ |
| “ | “ | “ |
| McGregor, Iowa | “ | “ |
| “ | “ | “ |
| Janesville, Wis | “ | “ |
| “ | “ | “ |
| “ | “ | “ |
| “ | “ | “ |
| “ | “ | “ |
| “ | “ | “ |
| Near Beloit, Wis | “ | “ |
| “ | “ | “ |
| “ | “ | “ |

## MUSEUM

SPECIMENS REGISTERED IN THE

| Serial No. | Obtained. | | Name. | Number of specimens |
|---|---|---|---|---|
| | When. | Whence. | | |
| 7558 | July, 1891 | Geol. Survey | Ptilodictya subrecta Ulrich | 2 |
| 7559 | " | " | Batostoma fertile ? Ulrich | 1 |
| 7560 | " | " | Rhinidictya trentonensis Ulrich | 1 |
| 7561 | " | " | Batostomella trentonensis Nicholson | 1 |
| 7562 | " | " | Ptilodictya falciformis var. acuminata James | 6 |
| 7563 | " | " | Rhinidictya | 1 |
| 7564 | " | " | Rhinidictya paupera Ulrich | 1 |
| 7565 | " | " | Dekayella | 8 |
| 7566 | " | " | Stellipora antheloidea Hall | 1 |
| 7567 | " | " | ? Hemiphragma ottawaense Foord | 2 |
| 7568 | " | " | Homotrypa | 111 |
| 7569 | " | " | Prasopora insularis Ulrich | 130 |
| 7570 | " | " | Prasopora simulatrix Ulrich | 33 |
| 7571 | " | " | Prasopora simulatrix ? Ulrich | 1 |
| 7573 | " | " | Prasopora simulatrix Ulrich | 71 |
| 7574 | " | " | Monotrypa nodosa Ulrich (M. S.) | 4 |
| 7575 | " | " | Trematopora ositida Ulrich, et al | 1 |
| 7576 | " | " | " " | 1 |
| 7577 | " | " | Draospora fragilis Billings | 2 |
| 7578 | " | " | Batostomella simulatrix Ulrich | 3 |
| 7579 | " | " | Undetermined ramose forms | Many |
| 7580 | " | " | Crepipora hemispherica ? Ulrich | 2 |
| 7581 | " | " | Monotrypella quadrata var. multituberculata Whit. | 1 |
| 7582 | " | " | Heterotrypa | 5 |
| 7583 | " | " | " | 1 |
| 7584 | " | " | Heterotrypa singularis Ulrich | 3 |
| 7585 | " | " | Ceramoporella irregularis Whitfield | 8 |
| 7586 | Aug., 1891 | " | Spatiopora | 3 |
| 7587 | " | " | " | 4 |
| 7589 | " | " | Batostomella variabile Ulrich | 10 |
| 7590 | " | " | Crepipora | 6 |
| 7591 | " | " | Prasopora contigua Ulrich | 4 |
| 7592 | " | " | Batostoma minnesotensis ? | 2 |
| 7593 | July, 1891 | " | Rhinidictya fidelis Ulrich | 1 |
| 7594 | " | " | " " " | 1 |
| 7595 | " | " | Leptotrypa hexagonalis Ulrich | 2 |
| 7596 | Aug., 1891 | " | Pachydictya acuta var. elegans Ulrich | 1 |
| 7597 | " | " | Stictoporella angularis var. intermedia Ulrich | 1 |
| 7598 | " | " | Rhinidictya septata Ulrich | 5 |
| 7599 | " | " | Stictoporella angularis var. intermedia Ulrich | 4 |
| 7600 | " | " | Homotrypa minnesotensis Ulrich | 1 |
| 7601 | " | " | Prasopora insularis Ulrich | 141 |
| 7602 | " | " | Monotrypa cumulata Ulrich | 1 |
| 7603 | " | " | Batostomella trentonensis Ulrich | 1 |
| 7606 | " | " | Batostoma | 6 |
| 7607 | " | " | Pachydictya acuta Hall, et al | 1 |
| 7608 | " | " | " " | 1 |
| 7609 | " | " | " " | 1 |
| 7611 | " | " | Prasopora insularis Ulrich | 19 |
| 7612 | " | " | Rhinidictya paupera Ulrich | 1 |
| 7613 | " | " | Batostoma humile Ulrich | 19 |
| 7614 | " | " | Basal expansion of undet. ramose bryozoans | 5 |
| 7615 | " | " | Callopora pulchera? Ulrich | 3 |
| 7616 | " | " | Pachydictya acuta Hall | 5 |
| 7617 | " | " | Stictoporella angularis Ulrich | 2 |
| 7618 | " | " | Hemiphragma irrasum Ulrich | 2 |
| 7619 | " | " | Pachydictya acuta Hall, et al | 18 |
| 7620 | " | " | Proboscina tumulosa Ulrich | 1 |
| 7621 | " | " | Rhinidictya mutabilis | 2 |
| 7622 | " | " | Prasopora conoidea Ulrich | 17 |
| 7623 | " | " | Pachydictya acuta Hall | 1 |
| 7624 | " | " | Crepipora? denticulata Ulrich | 2 |
| 7625 | " | " | Prasopora occultata Foord | 5 |
| 7626 | " | " | Monotrypa cumulata Ulrich | 6 |
| 7627 | " | " | Hemipragma irrasum Ulrich | 1 |
| 7628 | " | " | Prasopora insularis Ulrich | 10 |
| 7629 | " | " | Monotrypa cumulata Ulrich | 1 |
| 7631 | " | " | Monticulipora ramifera Ulrich | 3 |
| 7632 | " | " | Pachydictya acuta Hall | 1 |
| 7633 | " | " | Dekayia trentonensis Ulrich | 2 |
| 7635 | " | " | Monotrypa cumulata Ulrich | 6 |
| 7636 | " | " | Homotrypa similis Foord | 3 |
| 7637 | " | " | Prasopora insularis Ulrich | 8 |
| 7638 | " | " | Leptotrypa | 1 |

## ADDITIONS.—*Continued.*

### GENERAL MUSEUM IN 1889, 1890 AND 1891.

| Locality. | Formation. | Collector and remarks. |
|---|---|---|
| Near Beloit, Wis | Trenton | O. Schuchert. |
| Rockton, Ill | " | " |
| " | " | " |
| Neenah, Wis | Galena | " |
| " | " | " |
| " | " | " |
| " | " | " |
| " | " | " |
| " | " | " |
| " | " | " |
| " | " | " |
| " | " | " |
| " | " | " |
| " | " | " |
| Oshkosh, Wis | " | " |
| Iron Ridge, Wis | Cincinnati | " |
| " | " | " |
| " | " | " |
| " | " | " |
| " | " | " |
| " | " | " |
| " | " | " |
| " | " | " |
| " | " | " |
| " | " | " |
| " | " | " |
| " | " | " |
| Graf, Iowa | " | " |
| " | " | " |
| " | " | " |
| Dubuque, Iowa | Galena | " |
| McGregor, Iowa | Trenton | " |
| " | " | " |
| Mineral Point, Wis | " | " |
| " | " | " |
| " | " | " |
| Decorah, Iowa | Galena | " |
| " | Trenton | " |
| " | Galena | " |
| " | Trenton | " |
| " | " | " |
| " | Galena | " |
| " | " | " |
| " | " | " |
| Six m. s. of Cannon Falls, Minn | " | Scofield and Schuchert. |
| " " | " | " |
| " " | " | " |
| " " | " | " |
| " " | " | " |
| " " | " | " |
| " " | " | " |
| " " | " | " |
| " " | " | " |
| " " | " | " |
| Preston, Minn | Trenton | " |
| Six m. s. Cannon Falls, Minn | Galena | " |
| Two m. s. e. " | " | " |
| " " | " | " |
| " " | " | " |
| " " | " | " |
| " " | " | " |
| Chatfield, Minn | Trenton | W. H. Scofield. |
| Holden, Minn | Galena | " |
| " | " | " |
| " | " | " |
| Seven m. s. Cannon Falls, Minn | " | Scofield and Schuchert. |
| " " | " | " |
| " " | " | " |
| Kenyon, Minn | " | W. H. Scofield. |
| " | " | " |
| Nine m. s. Cannon Falls, Minn | " | Scofield and Schuchert. |
| 9 miles south Cannon Falls, Minn | " | " " |
| Warsaw, Minn | " | W. H. Scofield. |
| " " | " | " |

## MUSEUM

### SPECIMENS REGISTERED IN THE

| Serial No. | Obtained. | | Name. | Number of specimens |
|---|---|---|---|---|
| | When. | Whence. | | |
| 7639 | Aug., 1891. | Geol. Survey | Pachydictya acuta Hall | 5 |
| 7640 | “ | “ | Callopora multitabulata Ulrich | 6 |
| 7641 | “ | “ | Prasopora insularis Ulrich | 1 |
| 7642 | “ | “ | Monotrypa cumulata Ulrich | 1 |
| 7643 | “ | “ | Pachydictya acuta? Hall | 2 |
| 7644 | “ | “ | Prasopora insularis Ulrich | 1 |
| 7645 | “ | “ | Homotrypa similis Foord | 1 |
| 7646 | “ | “ | Pachydictya occidentalis? Ulrich | 3 |
| 7647 | “ | “ | Ceramoporella | 1 |
| 7649 | “ | “ | Callopora | 16 |
| 7650 | “ | “ | Stictoporella frondifera Ulrich | 2 |
| 7652 | “ | “ | Callopora multitabulata Ulrich | 5 |
| 7653 | “ | “ | Lichenaria typa W and S | 1 |
| 7654 | “ | “ | Trematopora primigenia Ulrich | 1 |
| 7655 | “ | “ | Homotrypa exilis Ulrich | 1 |
| 7656 | “ | “ | Crepipora? denticulata Ulrich | 4 |
| 7657 | “ | “ | Dekayella | 12 |
| 7658 | “ | “ | Prasopora | 2 |
| 7659 | “ | “ | Callopora multitabulata Ulrich | 9 |
| 7660 | “ | “ | Anolotichia impolita Ulrich | 2 |
| 7661 | “ | “ | Trematopora primigenia Ulrich | 3 |
| 7662 | “ | “ | Crepipora? denticulata Ulrich | 1 |
| 7663 | “ | “ | Rhinidictya mutabilis Ulrich | 1 |
| 7664 | “ | “ | Batostoma winchelli Ulrich | 22 |
| 7665 | “ | “ | Callopora multitabulata Ulrich | 5 |
| 7666 | “ | “ | Prasopora insularis Ulrich | 14 |
| 7667 | “ | “ | Homotrypa separata Ulrich | 1 |
| 7668 | “ | “ | Batostoma minnesotensis Ulrich | 2 |
| 7669 | “ | “ | Dekayella | 1 |
| 7670 | “ | “ | Homotrypa | 8 |
| 7671 | “ | “ | Lingula philomela Billings | 1 |
| 7672 | July, 1891. | “ | Lingula riciniformis var. galenensis W. and S | 3 |
| 7673 | “ | “ | “ “ “ “ “ | 10 |
| 7674 | Aug., 1891. | “ | Lingula hurlburti N. H. Winchell | 2 |
| 7675 | “ | “ | Lingula deflecta W. and S. | 7 |
| 7676 | “ | “ | Lingula deflecta Winchell and Schuchert? | 1 |
| 7677 | July, 1891. | “ | Lingula iowensis Owen | 11 |
| 7678 | “ | “ | “ “ | 5 |
| 7679 | Aug., 1891. | “ | “ “ | 2 |
| 7680 | “ | “ | “ “ | 8 |
| 7681 | “ | “ | Lingula canadensis Billings | 1 |
| 7682 | “ | “ | “ “ | 1 |
| 7683 | July, 1891. | “ | Lingulasma galenensis W. and S. | 1 |
| 7684 | “ | “ | “ “ | 1 |
| 7685 | “ | “ | “ “ | 3 |
| 7686 | Aug., 1891 | “ | “ “ | 1 |
| 7687 | July, 1891 | “ | Lingula trentonensis Conrad | 3 |
| 7688 | Aug., 1891 | “ | Schizotreta pelopea Billings | 7 |
| 7689 | July, 1891 | “ | “ “ “ | 1 |
| 7690 | “ | “ | “ “ “ | 1 |
| 7691 | Oct., 1890 | “ | Trematis huronensis Billings | 1 |
| 7692 | July, 1891 | “ | Crania setigera Hall | 4 |
| 7693 | Aug., 1891 | “ | “ “ “ | 2 |
| 7694 | July, 1891 | “ | “ “ “ | 3 |
| 7695 | “ | “ | “ “ “ | 2 |
| 7696 | “ | “ | “ “ “ | 1 |
| 7697 | “ | “ | Crania trentonensis Hall | 3 |
| 7698 | “ | “ | Lysocrania ulrichi Hall | 1 |
| 7699 | “ | “ | “ “ “ | 2 |
| 7700 | Aug., 1891 | “ | “ “ “ | 2 |
| 7701 | “ | “ | Lysocrania ulrichi ? Hall | 1 |
| 7702 | “ | “ | Rauffella filosa Ulrich | 3 |
| 7703 | “ | “ | “ “ “ | 17 |
| 7704 | “ | “ | “ “ “ | 4 |
| 7705 | “ | “ | Rauffella ? | 1 |
| 7706 | “ | “ | Probably the remains of some sponge | 2 |
| 7707 | “ | “ | Rauffella filosa Ulrich | 1 |
| 7708 | “ | “ | “ “ “ | 1 |
| 7709 | “ | “ | Cylindrocœlia minnesotensis Ulrich | 1 |
| 7711 | July, 1891 | “ | Hindia parva Ulrich | 19 |
| 7712 | Sept., 1890 | “ | Astylospongia | 2 |
| 7714 | July, 1891 | “ | Receptaculites oweni Hall | 6 |
| 7715 | Aug., 1891 | “ | “ “ “ | 10 |
| 7716 | “ | “ | “ “ “ | 1 |

## ADDITIONS.—*Continued.*

### GENERAL MUSEUM IN 1889, 1890 AND 1891.

| Locality. | Formation. | Collector and remarks. |
|---|---|---|
| Warsaw, Minn. | Galena | W. H. Scofield. |
| Mineola, Minn | " | " |
| " " | " | " |
| " " | " | " |
| " " | " | " |
| 4 miles S. W. Cannon Falls, Minn | " | Scofield and Schuchert. |
| " " " | " | " |
| " " " | " | " |
| " " " | " | " |
| Fountain, Minn | Trenton | " |
| " " | " | " |
| Preston, Minn | " | " |
| " " | " | " |
| " " | " | " |
| " " | " | " |
| Near Fountain, Minn | " | " |
| " " | " | " |
| " " | " | " |
| " " | " | " |
| " " | " | " |
| " " | " | " |
| " " | " | " |
| Preston, Minn | " | " |
| Near Fountain, Minn | " | " |
| " " | Galena | " |
| " " | " | " |
| Chatfield, Minn | Trenton | W. H. Scofield. |
| " " | " | " |
| " " | " | " |
| " " | " | " |
| Granger, Minn | Cincinnati | Mr. R. H. Hasse of Granger. |
| Neenah, Wis | Galena | C. Schuchert. |
| Oshkosh, Wis | " | " |
| Mantorville, Minn | " | W. H. Scofield. |
| Near Fountain, Minn | " | C. Schuchert. |
| Spring Valley, Minn | Cincinnati | " |
| Dubuque, Iowa | Galena | " |
| Decorah, Iowa | " | " |
| Near Aspelund, Minn | " | Scofield and Schuchert, |
| Mantorville, Minn | " | " |
| " " | " | C. Schuchert. |
| Hader, Minn | " | W. H. Scofield. |
| Neenah, Wis | " | C. Schuchert. |
| Oshkosh, Wis | " | " |
| Decorah, Iowa | " | " |
| Bear creek, S. of Hamilton, Minn | " | " |
| Janesville, Wis | Trenton | C. Schuchert. |
| Mantorville, Minn | Galena | Scofield and Schuchert. |
| Dubuque. Iowa | " | C. Schuchert. |
| Neenah, Wis | " | " |
| Minneapolis, Minn | Trenton | C. L. Herrick. |
| St. Paul, Minn | " | C. Schuchert. |
| Near Preston, Minn | " | Scofield and Schuchert. |
| Decorah, Iowa | " | C. Schuchert. |
| Mineral Point, Wis | " | " |
| Beloit, Wis | " | C. Schuchert, C. & N. W. R. R. quarries. |
| Janesville, Wis | " | C. Schuchert. |
| St. Paul, Minn | " | " |
| 6 miles south of Cannon Falls, Minn. | Galena | Scofield and Schuchert. |
| Near Fountain, Minn | Trenton | " " " |
| 7 miles south of Cannon Falls, Minn. | Galena | " " " |
| Near Fountain, Minn | Trenton | " " " |
| Near Preston, Minn | " | Scofield and Schuchert. |
| Decorah, Iowa | " | C. Schuchert. |
| " " | " | " |
| 2 miles S. E. of Cannon Falls, Minn. | Galena | Scofield and Schuchert. |
| 6 miles south of Cannon Falls, Minn. | " | " " " |
| 7 miles south of Cannon Falls, Minn. | " | " " " |
| 6 miles south of Cannon Falls, Minn. | " | " " " |
| Oshkosh, Wis | " | C. Schuchert. |
| Spring Valley, Minn | Niagara | N. H. Winchell. |
| Dubuque, Iowa | Galena | C. Schuchert. |
| 6 miles south of Cannon Falls, Minn. | " | W. H. Scofield and C. Schuchert. |
| Sec. 12, Holden, Goodhue Co., Minn. | " | " " " |

## MUSEUM

### SPECIMENS REGISTERED IN THE

| Serial No. | Obtained. | | Name. | Number of specimens |
|---|---|---|---|---|
| | When. | Whence. | | |
| 7717 | Aug. 1891 | Geol, survey | Receptaculites oweni Hall | 2 |
| 7718 | " | " | Receptaculites oweni ? Hall | 2 |
| 7719 | " | " | Receptaculites oweni Hall | 2 |
| 7720 | " | " | " " " | 2 |
| 7721 | " | " | " " " | 7 |
| 7722 | " | " | Receptaculites iowensis Owen | 2 |
| 7723 | " | " | Receptaculites fungosus Hall | 1 |
| 7724 | " | " | Receptaculites globularis Hall | 3 |
| 7725 | Sept., 1880. | " | Protarea vetusta Edwards & Haime | 1 |
| 7726 | Aug., 1891. | " | Columnaria alveolata Hall | 1 |
| 7732 | " | " | Cretaceous limonite | 1 |
| 7733 | " | Presented | Black oxide of manganese | Indef. |
| 7734 | July, 1891.. | Geol. survey | Columnaria alveolata Hall | 3 |
| 7735 | Sept., 1891. | " | Limestone concretion from slate (aininike) | 1 |
| 7736 | " | " | Chert | 1 |
| 7737 | July, 1891.. | " | Streptelasma profundum Hall | 13 |
| 7738 | " | " | " " | 20 |
| 7739 | " | " | " " | 2 |
| 7740 | " | " | " " | 156 |
| 7741 | Aug., 1891. | " | " " | 3 |
| 7742 | " | " | " " | 11 |
| 7743 | " | " | " " | 1 |
| 7744 | July, 1891.. | " | Streptelasma corniculum Hall? | 12 |
| 7745 | " | " | " " | 6 |
| 7746 | Aug., 1891.. | " | " " | 4 |
| 7747 | " | " | " " | 13 |
| 7748 | " | " | " " | 5 |
| 7749 | " | " | " " | 7 |
| 7750 | " | " | " " | 8 |
| 7751 | " | " | " " | 13 |
| 7752 | " | " | Streptelasma | 2 |
| 7753 | " | " | Streptelasma rusticum Billings | 12 |
| 7754 | July, 1891.. | " | " " | 7 |
| 7755 | Aug., 1891. | " | Diplograptus pristis (Hisinger) Hall | 4 |
| 7756 | July, 1891.. | " | Diplograptus pristis? (Hisinger) Hall | 2 |
| 7757 | " | " | Diplograptus putillus Hall | 1 |
| 7758 | " | " | Diplograptus pristis (Hisinger) Hall | 9 |
| 7759 | Aug., 1881.. | " | Climacograptus typicalis Hall | 5 |
| 7760 | " | " | Diplograptus putillus Hall | 2 |
| 7761 | " | " | Dictyonema | 1 |
| 7762 | July, 1891 | " | Orthis (Plectorthis) whitfieldi Winchell | 10 |
| 7763 | Aug., 1891 | " | " " " " | 10 |
| 7764 | " | " | " " " " | 6 |
| 7765 | " | " | Orthis (Plectorthis) plicatella Hall | 2 |
| 7766 | " | " | " " " " | 2 |
| 7767 | July, 1891 | " | Orthis (Dinorthis) pectinella Emmons | 1 |
| 7768 | Aug., 1891 | " | Orthis (Dinorthis) pectinella var. sweeneyi Winchell. | 3 |
| 7769 | July, 1891 | " | " " " " | 6 |
| 7770 | Aug., 1891 | " | Orthis (Dinorthis) meedsi var. germana W. and S. | 3 |
| 7771 | " | " | Orthis (Dinorthis) meedsi W. and S | 2 |
| 7772 | " | " | " " " " | 9 |
| 7773 | " | " | " " " " | 10 |
| 7774 | " | " | " " " " | 10 |
| 7775 | " | " | " " " " | 7 |
| 7776 | " | " | " " " " | 4 |
| 7777 | " | " | " " " " | 4 |
| 7778 | " | " | " " " " | 6 |
| 7779 | " | " | " " " " | 6 |
| 7780 | " | " | " " " " | 18 |
| 7781 | " | " | " " " " | 5 |
| 7782 | " | " | " " " " | 5 |
| 7783 | July, 1891 | " | " " " " | 4 |
| 7784 | " | " | " " " " | 7 |
| 7785 | " | " | Orthis (D.) pectinella var. sweeneyi Winchell | 8 |
| 7786 | Aug., 1891 | " | Orthis (D.) subquadrata Hall | Many |
| 7787 | Sept., 1881 | Presented | " " " | 3 |
| 7788 | Aug., 1891 | Geol. survey | " " " | 4 |
| 7789 | " | " | Orthis (D.) proavita W. and S | 7 |
| 7790 | July, 1891 | " | Orthis (D.) deflecta Conrad | 16 |
| 7791 | " | " | " " " | 9 |
| 7792 | " | " | " " " | 6 |
| 7793 | " | " | Orthis (Dinothis) deflecta Conrad | 3 |
| 7794 | " | " | " " | 5 |
| 7795 | Aug., 1891 | " | Orthis tricenaria Conrad | 2 |

## ADDITIONS.—*Continued.*

### GENERAL MUSEUM IN 1889, 1890 AND 1891.

| Locality, | Formation. | Collector and remarks. |
|---|---|---|
| Minneola, Minn. | Galena | W. H. Scofield and C. Schuchert. |
| Stewartsville, Minn. | " | " " " |
| 3 miles south of Cannon Falls, Minn. | " | " " " |
| Near Fountain, Minn | " | " " " |
| Decorah, Iowa | " | C. Schuchert. |
| " | " | " |
| " | " | " |
| Dubuque, Iowa | " | " |
| Spring Valley, Minn | Cincinnati | N. H. Winchell. |
| Preston, Minn | Trenton | C. Schuchert. |
| Winona county, Minn | | |
| Monticello, Minn | | By J. N. Stacy. |
| Rockton, Ill | Trenton | C. Schuchert. |
| Beaver Mine, Ont., Can | Aininike | H. V. Winchell. |
| " " | " | " |
| Rockton, Ill | Trenton | C. Schuchert. |
| Beloit, Wis. | " | " (Samp's quarry.) |
| Janesville, Wis | " | " |
| Mineral Point, Wis | " | " |
| Fountain Minn | " | Scofield and Schuchert. |
| Preston, Minn | " | " |
| Cannon Falls, Minn | " | " |
| Oshkosh, Wis | Galena | C. Schuchart. |
| Decorah, Iowa | Trenton | " |
| Nine miles S. ofCannon Falls, Minn. | Galena | Scofield and Schuchert. |
| Two m. S. E. of Cannon Falls, Minn. | " | " |
| Kenyon, Minn | " | " |
| Twelve m. S. of Cannon Falls, Minn. | " | " |
| Three m. S. of Cannon Falls, Minn | " | " |
| Seven m. S. of Cannon Falls, Minn | " | " |
| Florence, Iowa | Cincinnati | " |
| " | " | " |
| Graf, Iowa | " | C. Schuchert. |
| Granger, Minn | " | Scofield and Schuchert. |
| Graf, Iowa | " | C Schuchert. |
| " | " | |
| " | " | |
| Mantorville, Minn | Galena | Scofield and Schuchert. |
| Granger, Minn | Cincinnati | " |
| " " | " | " |
| Graf, Iowa | " | C. Schuchert. |
| Spring Valley, Minn | " | Scofield and Schuchert. |
| Near Granger ,Minn | " | " |
| 9 m. S. of Cannon Falls, Minn | Galena, | " |
| 12 m. S. of Cannon Falls, Minn | " | " |
| Decorah, Iowa | Trenton | C. Schuchert. |
| 2 m. S. of Cannon Falls, Minn | " | Scofield and Schuchert. |
| McGregor, Iowa | " | C. Schuchert. |
| 9 m. S. of Cannon Falls, Minn | Galena | Scofield and Schuchert. |
| McGregor, Iowa | Trenton | C. Schuchert. |
| 6 m. S. of Cannon Falls, Minn | Galena | Scofield and Schuchert. |
| 12 m. S. of Cannon Fall, Minn | " | " |
| 2 m. S. E. of Cannon Falls, Minn | " | " |
| 3 m. S. W. of Cannon Falls, Minn | " | " |
| 7 m. S. of Cannon Falls, Minn | " | " |
| Mineola, Minn | " | " |
| Warsaw, Minn | " | " |
| Kenyon, Minn | " | " |
| Fountain, Minn | " | " |
| Preston, Minn | Trenton | " |
| Decorah, Iowa | Galena | C. Schuchert. |
| Neenah, Wis | " | " |
| Oshkosh, Wis | " | " |
| Decorah, Iowa | Trenton | " |
| Spring Valley, Minn | Cincinnati | Scofield and Schuchert. |
| " " | " | John Kiechler (part of No. 4094) |
| Graf, Iowa | " | C. Schuchert. |
| Spring Valley, Minn | " | Scofield and Schuchert. |
| Janesville, Wis | Trenton | C. Schuchert. |
| Beloit, Wis | " | " |
| Mineral Point, Wis | " | " |
| McGregor, Iowa | " | " |
| Minneapolis, Minn | " | H. V. Winchell. |
| 2 m. S. of Cannon Falls, Minn | " | Scofield and Schuchert. |

## MUSEUM

### SPECIMENS REGISTERED IN THE

| Serial No. | Obtained. When. | Obtained. Whence. | Name. | Number of specimens. |
|---|---|---|---|---|
| 7796 | Aug., 1891 | Geol. Survey | Orthis testudinaria Conrad | 1 |
| 7797 | “ | “ | “ “ | 1 |
| 7798 | July, 1891 | “ | “ “ | 15 |
| 7799 | “ | “ | “ “ | 5 |
| 7800 | “ | “ | “ “ | 1 |
| 7801 | “ | “ | “ “ | 18 |
| 7802 | “ | “ | “ “ | 11 |
| 7803 | “ | “ | “ “ | 2 |
| 7804 | Aug., 1891 | “ | “ “ | 1 |
| 7805 | “ | “ | “ “ | 5 |
| 7806 | July, 1891 | “ | Orthis bellarugosa Conrad | 4 |
| 7807 | “ | “ | “ “ | 3 |
| 7808 | “ | “ | “ “ | 2 |
| 7809 | “ | “ | “ “ | 1 |
| 7810 | “ | “ | “ “ | 2 |
| 7811 | Aug., 1891 | “ | “ “ | 3 |
| 7812 | “ | “ | “ “ | 1 |
| 7813 | July, 1891 | “ | Orthis insculpta, subquadrata, etc. | 1 |
| 7814 | “ | “ | Orthis insculpta | 3 |
| 7815 | “ | “ | “ “ | 2 |
| 7816 | May, 1891 | Donation | Platystrophia biforata Schlotheim. | 1 |
| 7817 | Aug., 1891 | Geol. Survey | “ “ | 6 |
| 7818 | “ | “ | “ “ | 4 |
| 7819 | “ | “ | “ “ | 9 |
| 7820 | “ | “ | “ “ | 5 |
| 7821 | “ | “ | “ “ | 3 |
| 7822 | “ | “ | “ “ | 21 |
| 7823 | “ | “ | “ “ | 30 |
| 7824 | July, 1891 | “ | “ “ | 25 |
| 7825 | “ | “ | “ “ | 6 |
| 7826 | “ | “ | Platystrophia biforata Schlotheim. | 5 |
| 7827 | “ | “ | “ “ | 5 |
| 7828 | Aug., 1891 | “ | “ “ | 2 |
| 7829 | Nov., 1891 | Exchange | Monticulipora mammillata | 6 |
| 7834 | “ | “ | Orthis lynx | 25 |
| 7839 | “ | “ | Orthoceras | 3 |
| 7842 | “ | “ | Murchisonia major | 2 |
| 7846 | “ | “ | Receptaculites oweni | 1 |
| 7847 | “ | “ | Halysites catenulatus | 1 |
| 7848 | “ | “ | “ “ | 1 |
| 7849 | “ | “ | Favosites favosus | 1 |
| 7850 | “ | “ | Zaphrentis | 1 |
| 7852 | “ | “ | Aulopora cornuta | 1 |
| 7853 | “ | “ | Strombodes pentagoneus | 1 |
| 7854 | “ | “ | Favosites forbesi | 1 |
| 7855 | “ | “ | Stromoptera concentrica | 1 |
| 7856 | “ | “ | Favosites dumosus | 2 |
| 7857 | “ | “ | Lithographic limestone | 1 |
| 7858 | “ | “ | “ “ | 3 |
| 7859 | “ | “ | Syringopora harveyi | 1 |
| 7860 | “ | “ | Spirifera marionensis | 3 |
| 7861 | “ | “ | Styldlites | 2 |
| 7862 | “ | “ | Zapdrentis | 3 |
| 7863 | “ | “ | Zaphrentis elliptica | 3 |
| 7864 | “ | “ | Productus flemingi | 2 |
| 7866 | “ | “ | Productus punctatus? | 1 |
| 7867 | “ | “ | Rhynchonella ringens | 2 |
| 7868 | “ | “ | Athyris incrassata | 2 |
| 7869 | “ | “ | Spirifera grimesi | 3 |
| 7870 | “ | “ | Terebratula rowleyi | 1 |
| 7871 | “ | “ | Euomphalus latus | 2 |
| 7890 | “ | “ | Amethystine quartz | 1 |
| 7891 | “ | “ | Calcareous tufa | 1 |
| 7892 | July, 1891 | Geol. Survey | Orthis (Dalmanella) testudinaria | 2 |
| 7893 | “ | “ | “ “ “ | 5 |
| 7894 | “ | “ | “ “ “ | 6 |
| 7895 | Aug., 1891 | “ | “ “ “ | 16 |
| 7896 | “ | “ | Orthis (Dalmanella) hamburgensis ? Walcott | 5 |
| 7897 | “ | “ | Orthis (Dalmanella) testudinaria | 3 |
| 7898 | “ | “ | “ “ “ | 15 |
| 7899 | “ | “ | “ “ “ | 32 |
| 7900 | “ | “ | “ “ “ | 12 |
| 7901 | “ | “ | “ “ “ | 17 |
| 7902 | April, 1879 | “ | “ “ “ | 30 |

ADDITIONS.—*Continued.*

GENERAL MUSEUM, 1889, 1890 AND 1891.

| Locality. | Formation. | Collector and remarks. |
|---|---|---|
| Near Fountain, Minn | Trenton | Scofield and Schuchert. |
| Preston, Minn | " | " " |
| Janesville, Wis | " | C. Schuchert. |
| Beloit, Wis | " | " |
| Mineral Point, Wis | " | " |
| " " | " | " |
| Decorah, Iowa | " | " |
| McGregor. Iowa | " | " |
| 12 m. S. of Cannon Falls, Minn | Galena | Scofield and Schuchert. |
| 6 m. S. of " " | " | " " |
| Rockton, Ill | Trenton | C. Schuchert. |
| Neenah. Wis | Galena. | " |
| Janesville, Wis | Trenton | " |
| McGregor. Iowa | " | " |
| Decorah, Iowa | " | " |
| Near Fountain, Minn | Galena | Scofield and Schuchert. |
| Mineola, Minn | " | " " |
| Iron Ridge, Wis | Cincinnati | C. Schuchert. |
| " " | " | " |
| Graf, Iowa | " | " |
| Cannon Falls, Minn | Galena | Dr. Sandberg. |
| 6 m. S. of Cannon Falls, Minn | " | Scofield and Schuchert. |
| 12 m. S. of " " | " | " " |
| 3 m. S. of " " | " | " " |
| 2 m. S. E. of " " | " | " " |
| Kenyon, Minn | " | W. H. Scofield. |
| Near Fountain, Minn | " | Scofield and Schuchert. |
| Decorah, Iowa. | " | C. Schuchert. |
| Oshkosh, Wis. | " | " |
| Neenah Wis | " | " |
| Iron Ridge, Wis | Cincinnati | " |
| Graf, Iowa | " | " |
| Preston, Minn | Trenton | Scofield and Schuchert. |
| Louisville. Kentucky | Hudson River | From Rev. Wm. H. Barris. |
| Shelby county, Kentucky | Silurian | " |
| " " | " | " |
| Pike county, Mo | Trenton | " |
| Ralls county, Mo | " | " |
| Jones county, Iowa | ........ | " |
| " " | Silurian | " |
| " " | Niagara | " |
| " " | " | " |
| " " | Hamilton | " |
| " " | Niagara | " |
| " " | " | " |
| " " | " | " |
| Fort Erie, Canada | Hamilton | " |
| Pike county, Mo | Choteau | " |
| " | " | " |
| " | " | " |
| Marion county, Mo | " | " |
| " | Burlington | " |
| " | " | " |
| " | " | " |
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| " | " | " |
| " | " | " |
| " | " | " |
| " | " | " |
| " | " | " |
| Anderson county, S. C | ........ | " |
| Marion county, Mo | ........ | " |
| Rockton, Ill | Trenton | C. Schuchert. |
| Mineral Point, Wis | " | " |
| McGregor. Iowa | " | " |
| Decorah, Iowa | " | " |
| Preston, Minn | " | Scofield and Schuchert. |
| Fountain, Minn | " | " " |
| " " | Galena | " " |
| 2 miles S. E Cannon Falls | " | " " |
| 4 miles south of Cannon Falls, Minn. | " | " " |
| Mineola. Minn | " | W. H. Scofield. |
| Kenyon, Minn | " | N. H. Winchell. |

## MUSEUM

### SPECIMENS REGISTERED IN THE

| Serial No. | Obtained. | | Name. | Number of specimens |
|---|---|---|---|---|
| | When. | Whence. | | |
| 7903 | July, 1891 | Geol. Survey | Orthis (Dalmanella) testudinaria | 55 |
| 7904 | " | " | " " " | 3 |
| 7905 | " | " | " " " | 22 |
| 7906 | Aug., 1891 | " | " " " | 14 |
| 7907 | " | " | " " " | 1 slab. |
| 7908 | " | " | " " " | 4 |
| 7909 | " | " | " " " | 9 |
| 7940 | " | Exchange | Jacupirangite, pyroxene facies | 1 |
| 7941 | " | " | Jacupirangite, nepheline facies | 1 |
| 7942 | " | " | Jacupirangite | 1 |
| 7943 | " | " | Jacupirangite, magnetite facies | 1 |
| 7944 | " | " | Magnetite bearing rock | 1 |
| 7945 | " | " | " " " | 1 |
| 7946 | " | " | " " " | 1 |
| 7958 | " | Geol. Survey | Crania setigera Hall | 1 |
| 7959 | July, 1891 | " | Orthis (Dalmanella) subæquata Conrad | 5 |
| 7960 | " | " | " " " " | 13 |
| 7961 | " | " | " " " " | Indef. |
| 7962 | " | " | " " " " | 7 slabs. |
| 7963 | Aug., 1891 | " | " " " " | 18 |
| 7964 | " | " | " " " " | 16 |
| 7965 | " | " | " " " " | 9 |
| 7966 | " | " | " " " " | 4 |
| 7967 | " | " | " " " " | 12 |
| 7968 | " | " | " " " " | 10 |
| 7969 | July, 1891 | " | Orthis (D.) subæquata var. gibbosa Billings | 1 |
| 7970 | Aug., 1891 | " | " " " " | Inde |
| 7971 | " | " | " " " " | 1 |
| 7972 | | " | " " " " | 3 |
| 7973 | July, 1891 | " | Orthis (D.) subæquata var. perveta Conrad | 5 |
| 7974 | " | " | " " " " | 1 |
| 7975 | " | " | " " " " | 3 |
| 7976 | " | " | " " " " | 3 |
| 7977 | .......... | " | " " " " | 7 |
| 7978 | 1876-1879 | " | Orthis (D.) subæquata var. conradi Winchell | 1 |
| 7979 | " | " | " " " " | 5 |
| 7980 | July, 1891 | " | " " " " | 4 |
| 7981 | " | " | " " " " | 3 |
| 7982 | " | " | " " " " | 1 |
| 7983 | Aug., 1891 | " | Lingula riciniformis var. galenensis W. and S. | 1 |
| 7984 | July, 1891 | " | Stictoporella angularis var intermedia Ulrich | 2 |
| 7985 | Aug., 1891 | " | Orthis testudinaria var. meeki. | Indef. |
| 7986 | July, 1891 | " | Streptelasma profundum Hall | 27 |
| 7987 | " | " | Fenestella granulosa Whitfield | Slab. |
| 7988 | " | " | Fistulipora (??) solidissima Whitfield. | 14 |
| 7989 | " | " | Batostomella | 6 |
| 7990 | " | " | Constellaria insincera Ulrich (MS.) | 3 |
| 7991 | " | " | Batostomella simulatrix Ulrich | 4 |
| 7992 | " | " | Trematopora annulifera Whitfield | 1 |
| 7993 | " | " | Batostomella | 13 |
| 7996 | " | " | Homotrypa | 6 |
| 7997 | " | " | ? Fistulipora lens Whitfield | 3 |
| 7998 | " | " | Monotrypella quadrata var. rectangularis Whitfield | 16 |
| 7999 | " | " | Batostoma | 10 |
| 8000 | " | " | " | 8 |
| 8001 | " | " | Atactoporella | 3 |
| 8002 | " | " | Callopora | 2 |
| 8003 | " | " | Callopora rugosa Whitfield | 12 |
| 8004 | " | " | Homotrypella | 6 |
| 8005 | " | " | Atactoporella | 8 |
| 8006 | " | " | Constellaria polystomella Nich | 1 |
| 8009 | " | " | Ceramoporella granulosa Ulrich | 11 |
| 8010 | " | " | Ceramoporella minima Ulrich (MS) | 5 |
| 8011 | " | " | Crepipora simulans Ulrich | 1 |
| 8012 | " | " | Anolotichia ponderosa Ulrich | 1 |
| 8013 | " | " | Stromotopora arachnoidea Hall | 2 |
| 8014 | " | " | Batostoma | 8 |
| 8015 | " | " | Batostomella gracilis Nicholson | 1 |
| 8016 | " | " | Batostomella simulatrix Ulrich | 4 |
| 8017 | " | " | Monotrypella multituberculata Whitf | 2 |
| 8018 | " | " | Monotrypella rectangularis Whitf | 5 |
| 8019 | " | " | Callopora crenulata Ulrich. | 1 |
| 8020 | " | " | Callopora multitabulata Ulrich | 17 |
| 8021 | " | " | Homotrypa similis Foord | 4 |

ADDITIONS.—*Continued.*

GENERAL MUSEUM IN 1889, 1890 AND 1891.

| Locality. | Formation. | Collector and remarks. |
|---|---|---|
| Granger. Minn | Galena | Scofield and Schuchert. |
| Dubuque, Iowa | " | C. Schuchert. |
| Oshkosh, Wis | " | " |
| Neenah, Wis | " | " |
| Decorah, Iowa | " | " |
| Graf, Iowa | Cincinnati | " |
| Iron Ridge, Wis | " | " |
| Jacupiranga, Brazil | | O. A. Derby. |
| " " | | " |
| " " | | " |
| " " | | " alteration to mica and then to secondary silica. |
| Ipanema. Brazil | | " alteration to secondary silica. |
| " " | | " alteration, with barite, tridymite, etc |
| " " | | " alteration, with secondary silica. |
| Chatfield, Minn | Trenton | W. H. Scofield. |
| Mineral Point, Wis | " | C. Schuchert. |
| McGregor, Iowa | " | " |
| Decorah, Iowa | " | " |
| " " | " | " |
| Preston, Minn | " | Scofield and Schuchert. |
| Fountain. Minn | " | " " " |
| Chatfield, Minn | " | W. H. Scofield. |
| 2 m. S. E. of Cannon Falls, Minn | " | Scofield and Schuchert. |
| Minneapolis, Minn | " | C. L. Herrick. |
| St. Paul, Minn | " | C. Schuchert. |
| Mineral Point, Wis | " | " |
| Chatfield. Minn | " | Scofield and Schuchert. |
| Decorah, Iowa | " | C. Schuchert. |
| Minneapolis, Minn | " | C. L. Herrick. |
| Janesville, Wis | " | C. Schuchert. |
| Beloit, Wis | " | " |
| Mineral Point. Wis | " | " |
| Decorah, Iowa | " | " |
| Near Fountain, Minn | " | N. H. Winchell. |
| Minneapolis, Minn | " | C. L. Herrick (From No. 5088.) |
| " " | " | " |
| Janesville, Wis | " | C. Schuchert. |
| Beloit, Wis | " | " |
| Decorah, Iowa | " | " |
| Fountain. Minn | Galena | Scofield and Schuchert. |
| Preston, Minn | Trenton | " " |
| Spring Valley, Minn | Hudson River | " " |
| Decorah, Iowa | Trenton | C. Schuchert. |
| Iron Ridge, Wis | Hudson River | " |
| Near Iron Ridge, Wis | " | " |
| " " " | " | " |
| " " " | " | " |
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| " " " | " | " |
| " " " | " | " |
| Graf, Iowa | " | " |
| " " | " | " |
| " " | " | " |
| " " | " | " |
| " " | " | " |
| 6 m. S. Cannon Falls, Minn | Galena | Scofield and Schuchert. |
| " " " | " | " " |
| " " " | " | " " |

## MUSEUM

### SPECIMENS REGISTERED IN THE

| Serial No. | Obtained. | | Name. | Number of specimens |
|---|---|---|---|---|
| | When. | Whence. | | |
| 7796 | Aug., 1891 | Geol. Survey | Orthis tricenaria Conrad | 1 |
| 7797 | " | " | " " | 5 |
| 7798 | July, 1891 | " | " " | 35 |
| 7799 | " | " | " " | 5 |
| 7800 | " | " | " " | 3 |
| 7801 | " | " | " " | 14 |
| 7802 | " | " | " " | 10 |
| 7803 | " | " | " " | 2 |
| 7804 | Aug., 1891 | " | " " | 7 |
| 7805 | " | " | " " | 5 |
| 7806 | July, 1891 | " | Orthis bellarugosa Conrad | 4 |
| 7807 | " | " | " " | 3 |
| 7808 | " | " | " " | 2 |
| 7809 | " | " | " " | 2 |
| 7810 | " | " | " " | 2 |
| 7811 | Aug., 1891 | " | " " | 3 |
| 7812 | " | " | " " | 3 |
| 7813 | July, 1891 | " | Orthis insculpta, subquadrata, etc | 1 |
| 7814 | " | " | Orthis insculpta | 3 |
| 7815 | " | " | " " | 2 |
| 7816 | May, 1885 | Donation | Platystrophia biforata Schlotheim | 1 |
| 7817 | Aug., 1891 | Geol. Survey | " " | 8 |
| 7818 | " | " | " " | 8 |
| 7819 | " | " | " " | 9 |
| 7820 | " | " | " " | 5 |
| 7821 | " | " | " " | 3 |
| 7822 | " | " | " " | 21 |
| 7823 | " | " | " " | 20 |
| 7824 | July, 1891 | " | " " | 25 |
| 7825 | " | " | " " | 5 |
| 7826 | " | " | Platystrophia biforata Schlotheim | 5 |
| 7827 | " | " | " " | 5 |
| 7828 | Aug., 1891 | " | " " | 2 |
| 7829 | Nov., 1891 | Exchange | Monticulipora mammillata | 6 |
| 7834 | " | " | Orthis lynx | 26 |
| 7839 | " | " | Orthoceras | 3 |
| 7842 | " | " | Murchisonia major | 2 |
| 7846 | " | " | Receptaculites oweni | 1 |
| 7847 | " | " | Halysites catenulatus | 1 |
| 7848 | " | " | " " | 1 |
| 7849 | " | " | Favosites favosus | 1 |
| 7850 | " | " | Zaphrentis | 1 |
| 7852 | " | " | Aulopora cornuta | 1 |
| 7853 | " | " | Strombodes pentagoneus | 1 |
| 7854 | " | " | Favosites forbesi | 1 |
| 7855 | " | " | Stromoptera concentrica | 1 |
| 7856 | " | " | Favosites dumosus | 2 |
| 7857 | " | " | Lithographic limestone | 1 |
| 7858 | " | " | " " | 3 |
| 7859 | " | " | Syringopora harveyi | 1 |
| 7860 | " | " | Spirifera marionensis | 3 |
| 7361 | " | " | Styldlites | 2 |
| 7862 | " | " | Zapdrentis | 3 |
| 7863 | " | " | Zaphrentis elliptica | 3 |
| 7865 | " | " | Productus flemingi | 2 |
| 7866 | " | " | Productus punctatus? | 1 |
| 7667 | " | " | Rhynchonella ringens | 2 |
| 7568 | " | " | Athyris incrassata | 2 |
| 7869 | " | " | Spirifera grimesi | 3 |
| 7870 | " | " | Terebratula rowleyi | 1 |
| 7871 | " | " | Euomphalus latus | 2 |
| 7890 | " | " | Amethystine quartz | 1 |
| 7891 | " | " | Calcareous tufa | 1 |
| 7892 | July, 1891 | Geol. Survey | Orthis (Dalmanella) testudinaria | 2 |
| 7893 | " | " | " " " | 5 |
| 7894 | " | " | " " " | 6 |
| 7795 | Aug., 1891 | " | " " " | 16 |
| 7896 | " | " | Orthis (Dalmanella) hamburgensis ? Walcott | 5 |
| 7897 | " | " | Orthis (Dalmanella) testudinaria | 3 |
| 7898 | " | " | " " " | 15 |
| 7899 | " | " | " " " | 32 |
| 7900 | " | " | " " " | 12 |
| 7901 | " | " | " " " | 17 |
| 7902 | April, 1879 | " | " " " | 30 |

ADDITIONS.—*Continued.*

GENERAL MUSEUM, 1889, 1890 AND 1891.

| Locality. | Formation. | Collector and remarks. |
|---|---|---|
| Near Fountain, Minn | Trenton | Scofield and Schuchert. |
| Preston, Minn | " | " " |
| Janesville, Wis | " | C. Schuchert. |
| Beloit, Wis | " | " |
| Mineral Point, Wis | " | " |
| " " | " | " |
| Decorah, Iowa | " | " |
| McGregor, Iowa | " | " |
| 12 m. S. of Cannon Falls, Minn | Galena | Scofield and Schuchert. |
| 6 m. S. of " " | " | " " |
| Rockton, Ill | Trenton | C. Schuchert. |
| Neenah, Wis | Galena. | " |
| Janesville, Wis | Trenton | " |
| McGregor, Iowa | " | " |
| Decorah, Iowa | " | " |
| Near Fountain, Minn | Galena | Scofield and Schuchert. |
| Mineola, Minn | " | " " |
| Iron Ridge, Wis | Cincinnati | C. Schuchert. |
| " " | " | " |
| Graf, Iowa | " | " |
| Cannon Falls, Minn | Galena | Dr. Sandberg. |
| 6 m. S. of Cannon Falls, Minn | " | Scofield and Schuchert. |
| 12 m. S. of " " | " | " " |
| 3 m. S. of " " | " | " " |
| 2 m. S. E. of " " | " | " " |
| Kenyon, Minn | " | W. H. Scofield. |
| Near Fountain, Minn | " | Scofield and Schuchert. |
| Decorah, Iowa | " | C. Schuchert. |
| Oshkosh, Wis. | " | " |
| Neenah Wis | " | " |
| Iron Ridge, Wis | Cincinnati | " |
| Graf, Iowa | " | " |
| Preston, Minn | Trenton | Scofield and Schuchert. |
| Louisville, Kentucky | Hudson River | From Rev. Wm. H. Barris. |
| Shelby county, Kentucky | Silurian | " |
| " " | " | " |
| Pike county, Mo | Trenton | " |
| Ralls county, Mo | " | " |
| Jones county, Iowa |  | " |
| " " | Silurian | " |
| " " | Niagara | " |
| " " | " | " |
| " " | Hamilton | " |
| " " | Niagara | " |
| " " | " | " |
| " " | " | " |
| Fort Erie, Canada | Hamilton | " |
| Pike county, Mo | Choteau | " |
| " | " | " |
| " | " | " |
| Marion county, Mo | " | " |
| " | Burlington | " |
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| " | " | " |
| " | " | " |
| " | " | " |
| " | " | " |
| Anderson county, S. C |  | " |
| Marion county, Mo |  | " |
| Rockton, Ill | Trenton | C. Schuchert. |
| Mineral Point, Wis | " | " |
| McGregor, Iowa | " | " |
| Decorah, Iowa | " | " |
| Preston, Minn | " | Scofield and Schuchert. |
| Fountain, Minn | " | " " |
| " " | Galena | " " |
| 2 miles S. E Cannon Falls | " | " " |
| 4 miles south of Cannon Falls, Minn. | " | " " |
| Mineola, Minn | " | W. H. Scofield. |
| Kenyon, Minn | " | N. H. Winchell. |

## MUSEUM

### SPECIMENS REGISTERED IN THE

| Serial No. | Obtained. | | Name. | Number of specimens |
|---|---|---|---|---|
| | When. | Whence. | | |
| 8022 | July, 1891 | Geol. Survey | Dekayia trentonensis Ulrich | 1 |
| 8023 | “ | “ | Petigopora asperula Ulrich | 1 |
| 8024 | “ | “ | Prasopora contigua Ulrich | 11 |
| 8025 | “ | “ | Monotrypa cumulata Ulrich | 1 |
| 8026 | Aug., 1891 | “ | Basal portion of Batostoma species | 1 |
| 8027 | “ | “ | Pachydictya acuta Hall | 1 |
| 8028 | “ | “ | Phylloporina reticulata Hall | 1 |
| 8029 | “ | “ | Dekayia trentonensis Ulrich | 2 |
| 8030 | “ | “ | Homotrypa subramosa | 10 |
| 8031 | “ | “ | Ceramoporella | 2 |
| 8032 | “ | “ | Hemiphragma peculiare Ulrich | 1 |
| 8033 | “ | “ | Hemiphragma irrasum Ulrich | 2 |
| 8034 | “ | “ | Batostomella trentonensis Nicholson | 13 |
| 8035 | “ | “ | Monticulipora ramifera Ulrich | 4 |
| 8037 | “ | “ | Prasopora conoidea Ulrich | 2 |
| 8038 | “ | “ | Callopora crenulata Ulrich | 1 |
| 8039 | “ | “ | Calopora multitabulata Ulrich | 27 |
| 8040 | “ | “ | Batostomella trentonensis Nicholson | 6 |
| 8041 | “ | “ | Hemiphragma irrasum Ulrich | 5 |
| 8042 | “ | “ | Hemiphragma peculiare Ulrich | 2 |
| 8043 | “ | “ | Homotrypa similis Foord | 1 |
| 8044 | “ | “ | Constellaria incipiens Ulrich | 1 |
| 8045 | “ | “ | Stomatopora inflata Hall | 1 |
| 8046 | “ | “ | Prasopora insularis Ulrich | 6 |
| 8047 | “ | “ | Probiscina tumulosa Ulrich | 1 |
| 8048 | “ | “ | Monticulipora ramifera Ulrich | 3 |
| 8049 | “ | “ | Callopora multitabulata Ulrich | 25 |
| 8050 | “ | “ | Batostomella trentonensis Nicholson | 12 |
| 8051 | “ | “ | Hemiphragma irrasum Ulrich | 4 |
| 8052 | “ | “ | Hemiphragma peculiare Ulrich | 5 |
| 8053 | “ | “ | Ceramoporella | 1 |
| 8055 | “ | “ | Solenopora compacta Billings | 1 |
| 8056 | “ | “ | Batostoma | 3 |
| 8057 | “ | “ | Prasopora insularis Ulrich | 2 |
| 8058 | “ | “ | Homotrypa similis Foord | 9 |
| 8059 | July, 1891 | “ | Diploporella obliquata Ulrich (MS.) | 1 |
| 8060 | “ | “ | Leptotrypa acervulosa Ulrich | 14 |
| 8061 | “ | “ | Homotrypa subramosa Ulrich | 4 |
| 8062 | “ | “ | Monticulipora ramifera Ulrich | 4 |
| 8063 | “ | “ | Batastoma humile Ulrich | 4 |
| 8064 | “ | “ | Hemiphragma irrasum Ulrich | 3 |
| 8065 | “ | “ | Petigopora | 1 |
| 8066 | “ | “ | Stomatopora proutana Miller | 1 |
| 8067 | “ | “ | Callopora multitabulata Ulrich | 11 |
| 8068 | “ | “ | Callopora crenulata? Ulrich | 2 |
| 8069 | “ | “ | Nematopora ovalis Ulrich | 1 |
| 8070 | “ | “ | Homotrypa minnesotensis Ulrich | 14 |
| 8071 | “ | “ | Homotrypa | 1 |
| 8072 | “ | “ | Batostoma fertile? Ulrich | 2 |
| 8073 | “ | “ | Dekayella | 1 |
| 8074 | “ | “ | Nicholsonella | 1 |
| 8075 | “ | “ | Arthropora simplex Ulrich | 1 |
| 8076 | “ | “ | Rhinidictya nicholsoni Ulrich | 1 |
| 8077 | “ | “ | Batostoma | 15 |
| 8078 | “ | “ | Hemiphragma irrasum Ulrich | 3 |
| 8079 | “ | “ | Batostomella trentonensis Ulrich | 6 |
| 8080 | “ | “ | Homotrypella | 5 |
| 8081 | “ | “ | Batostomella nana Ulrich | 1 |
| 8082 | “ | “ | ? Callopora crenulata Ulrich | 3 |
| 8083 | “ | “ | Callopora multitabulata Ulrich | 6 |
| 8084 | “ | “ | Batostomella | 6 |
| 8086 | “ | “ | Monticulipora | 10 |
| 8087 | Aug., 1891 | “ | Batostoma? | 6 |
| 8088 | “ | “ | Callopora angularis Ulrich | 8 |
| 8089 | “ | “ | Atactopora typicalis var. praecursor Ulrich | 1 |
| 8090 | “ | “ | Homotrypa minnesotensis Ulrich | 2 |
| 8091 | “ | “ | Homotrypa exilis Ulrich | 1 |
| 8092 | “ | “ | Batostoma winchelli Ulrich | 5 |
| 8093 | “ | “ | Batostoma minnesotensis? | 1 |
| 8094 | “ | “ | Atactoporella typicalis var. praecursor Ulrich | 1 |
| 8095 | “ | “ | Batostoma winchelli var. Ulrich | 2 |
| 8096 | “ | “ | Callopora multitabulata Ulrich | 7 |
| 9097 | “ | “ | Callopora angularis Ulrich | 1 |
| 8098 | “ | “ | Dekayella | 6 |
| 8099 | “ | “ | Homotrypa subramosa Ulrich | 2 |
| 8100 | “ | “ | Bythopora herricki Ulrich | 2 |

ADDITIONS—*Continued.*

GENERAL MUSEUM, 1889, 1890 AND 1891.

| Locality. | Formation. | Collector and remarks. |
|---|---|---|
| 6 m. S. of Cannon Falls, Minn | Galena | Scofield and Schuchert. |
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| Kenyon, Minn | " | W. H. Scofield. |
| Holden, Minn | " | " |
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| Decorah, Iowa | " | C. Schuchort. |
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| Chatfield, Minn | Trenton | W. H. Scofield. |
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| Near Fountain, Minn | " | Scofield and Schuchert. |
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## VII.

## CATALOGUE OF THE METEORITES IN THE UNIVERSITY COLLECTION, WITH REFERENCES TO LITERATURE DESCRIBING THEM.

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A number is given to each fall represented in the collection. Where there are several specimens from the same fall small italicized letters are used. A complete bibliography of the following meteorites has not been attempted, but under each fall we have tried to give the reference to the first description, and to other articles containing exhaustive descriptions, or new facts not mentioned in the first description. The catalogue is arranged chronologically as to the dates of fall or discovery.

No. 1. **Medvedewa, Krasnojarsk, Siberia. [The Pallas Iron.]** Found in 1749. Museum number, 4119.

G. Rose; Pogg. Ann., 1825, iv, p. 186.

N. von Kokscharow; Bull. l'Acad. Imp. Soc. St.-Pétersbourg, 1870, xx, No. 3.—Mémoires l'Acad. Imp. Soc. St.-Pétersbourg, xv, No. 6.—Jahrb. Mineralogie, 1870, p. 778.

A. Langier; Mem. Mus. Hist. Nat., 1817, iii, pp. 341-352.

E. H. von Baumhauer; Archives Néerlandaises, 1871, vi.

G. von Helmersen; Zeitsch. Deutsch. Geol. Gesell., xxv, p. 347. A Goebel; Bull. Ac. Imp. Sc., St.-Pétersbourg, 1874, xx, p. 100.

Iron. Irregular ragged specimen of a coarse metallic sponge, enclosing olivine in more or less rounded cavities. Most of the olivine has fallen out. Weight, 144 grams.

*[By exchange with Yale College.]*

No. 2. **Istlahuaca, Toluca, Mexico.** Found in 1784. Museum number, 4694.

Gazeta de Mexico, 1784-'85, vol. i, pp. 146, 200.

W. J. Taylor, Proceed. Acad. Nat. Sci. Phila., 1856, vol. viii, pp. 128-130.—Am. Jour. Sci., 1856, [2], xxii, pp. 374-376.

Iron. Irregular rusted piece. Two sides polished, one of them showing well marked Widmannstättian figures. Weight, 105.6 grams.

*[By exchange with Prof. C. U. Shepard.]*

No. 3. **Zacatecas, Mexico.** Found in 1792. Museum number, 4696.

C. Bergmann; Neues Jahrb. Min., 1856, p. 297.

H. Mueller; Quart. Jour. Chem. Soc., 1859, xi, pp. 236–240.

*a.* Iron. Irregular fragment. One side polished, the others rusted. Weight, 1.45 grams.

*b.* Smaller rusted fragments similar to *a.* Weight, 2.18 grams.

[*By exchange with Prof. C. U. Shepard.*]

No. 4. **Albacher Muehle, Bitburg, Rhenish Prussia.** Found in 1802. Museum number, 4416.

J. F. John; Jour. Chemie u. Physik, 1826, xlvi, p. 386.

Iron. Small fragment, much rusted and similar in appearance to the Ovifak iron. Weight, 4.55 grams.

[*By exchange with Prof. C. U. Shepard.*]

No. 5. **Durango, Mexico.** Found in 1804(?). Museum number, 4419.

Iron. Fragment which has been hammered and one end broken off. Weight, 10 grams.

[*By exchange with Prof. C. U. Shepard.*]

No. 6. **Weston, Fairfield Co., Connecticut.** Fell at 6:30 a. m., Dec. 14, 1807. Museum number, 4122.

Profs. Silliman and Kingsley; Am. Jour. Sci., 1869 [2], xlvii, pp. 1–8.

(This account is reproduced from the Memoirs of the Connecticut Academy of Arts and Sciences)

Stone. Gray ground-mass holding chondri and grains of iron scattered through it. Fragment with a small portion of the crust attached. Weight, 5 grams.

[*By exchange with Yale College.*]

No. 7. **Stannern, Iglau, Moravia.** Fell at 6 a. m., May 22, 1808. Museum number, 4408.

J. Moser; Ann. Physik, 1808, xxix, pp. 309–327.

C. Rammelsberg; Ann. Physik, 1851, lxxxiii, pp. 591–597.

G. Tschermak; Min. Mittheil., 1872, heft ii, p. 83.

*a.* Stone. Light gray fragment. One face has a black vitreous crust. Weight, 0.95 grams.

*b.* Smaller fragment of the same. One side shows crust. Weight, 0.4 gram.

*c.* Smaller fragments. Weight, 0.13 gram.

[*By exchange with Prof. C. U. Shepard.*]

No. 8. **Babb's Mill, Green Co., Tennessee.** Found in 1818. Museum number, 3351.

G. Troost; Am. Jour. Sci., 1845, [1], xlix, pp. 342–344.
C. U. Shepard; Am. Jour. Sci., 1847, [2], iv, pp. 76–77.
W. S. Clark; Metallic meteorites, 1852, pp. 65–66.

Iron. Thin slab; one side has been polished and etched but shows no distinct figures. Two of the edges show crust. Weight, 21 grams. "Its color is rather whiter than that of pure iron; and it is very malleable, equal, if not superior, in this respect to the softest wrought iron." (Am. Jour. Sci., [1], xlix, p. 343.)

[*By exchange with Prof. J. L. Smith.*]

No. 9. **Juvenas, Ardeche, France.** Fell at 3:30 p. m., June 15, 1821. Museum number, 3339.

L. N. Vauquelin; Ann. Chemie u. Physik, 1821, xviii, pp. 421–423.
A. Langier; Ann. Chemie u. Physik, 1821, xix, pp. 264–273.
C. Rammelsberg; Ann. Physik. Chemie, 1838, lxxviii, pp. 585–500.

*a*. Stone. Fine grained, gray, crumbling, showing almost no iron. Weight, 0.98 grams.

*b*. Two smaller fragments of the same, showing part of a black vitreous crust. Weight, 0.42 grams.

*c*. Four smaller fragments. No crust. Weight, 0.42 grams.

[*By exchange with Prof. J. L. Smith.*]

No. 10. **Coahuila, Mexico.** Museum numbers, 3349 and 3361. Found in 1827 (?). Museum numbers, 3349 (*b*), 3361 (*a*).

J. L. Smith; Amer. Jour. Sci., 1855, [2], xix, pp. 160–161; 1869, [2], xlvii, pp. 383–385; 1876, [3], xii, pp. 109–110; 1878, [3], xvi, pp. 270–272.

*a*. Iron. Rectangular block, with five faces polished, the sixth face showing a dull brown rusted surface. Weight, 3060 grams.

*b*. Daubréelite from the above meteorite. Weight, 0.0562 grams.

[*By exchange with Prof. J. L. Smith.*]

No. 11. **Drake Creek, near Nashville, Tennessee.** Fell at 4 p. m., May 9, 1827. Museum number, 3353.

H. Seybert; Am. Jour. Sci., 1830, [1], xvii, pp. 326–328.
E. H. Baumhauer; Ann. Physik. Chemie, 1845, lxvi, pp. 498–503.

*a*. Stone. Gray, fine-grained groundmass, with many small grains of iron. One face has a dull brown crust. Weight, 13.5 grams.

*b*. A smaller fragment of the same. Weight, 2 grams.

[*By exchange with Pro J. L. Smith.*]

No. 12. **Vouille, Poitiers, Vienne, France.** Fell July 18, 1831. Museum number, 4697.

Stone. Gray, sprinkled with bright iron grains. No crust. Weight, 0.4 gram.

[*By exchange with Prof. C. U. Shepard.*]

No. 13. **Coahuila, Mexico. [Butcher Irons.** Found in 1837. Museum number, 3358.

J. L. Smith; Am. Jour. Sci., 1855, [2], xix, pp. 160–161; 1867, [2], xliii, pp. 384–385; 1869, [2], xlvii, pp. 383–385.

Iron. Cut slab, not polished ; one side shows a grain o daubréelite surrounded by troilite. Weight, 67.35 grams.

[*By exchange with Prof. J. L. Smith.*]

No. 14. **Cold Bokkeveld, Cape of Good Hope, Africa.** Fell at 9 a. m., Oct. 13, 1838, Museum number, 3341.

M. Faraday; Philosoph. Trans., 1839, pp. 83–87.

E. P. Harris; Sitz. Wien Akad., 1859, xxxv, pp. 5–12.

Stone. Black, with white specks, but apparently no iron. Weight, 1.45 grams.

[*By exchange with Prof. J. L. Smith.*]

No. 15. **Pine Bluff, Little Piney, Missouri.** Fell at 3:30 p. m., Feb. 13, 1839. Museum number, 4,410.

C. U. Shepard; Am. Jour. Sci., 1840, [1], xxxix, pp 254–255.

Stone. Light gray, with darker grains and small specks of iron scattered through it. Fragment, without crust. Weight, 1.4 grams.

[*By exchange with Prof. C. U. Shepard*]

No. 16. **Putnam County, Georgia.** Found in 1839. Museum number, 4693.

J. E. Willet; Am. Jour. Sci., 1854, [2], xvii, pp. 331-332.

Iron. Small irregular fragment, much rusted. Weight, 34 grams.

[*By exchange with Prof. C. U. Shepard.*]

No. 17. **Coney Fork, Carthage, Smith County, Tennessee.** Found in 1840. Museum number, 3348.

E. Boricky; Neues Jahrb. Min., 1866, pp. 808-810.

[illegible] with three cut faces at right angles [illegible] these faces are polished and two [illegible] Widmanstättian figures. Weight [illegible] grams.

*[Exchange with Prof. [illegible]]*

**[illegible]anicza, Arva, Hungary.** Found in 18[illegible]

[illegible] Min., 1849, p. [illegible]

[illegible] Chemie, 18[illegible], pp. [illegible]

[illegible] Sci., 187[illegible], [illegible] x, pp. [illegible]

[illegible] one face polished, another [illegible] made up of bright nickel-[illegible] grams.

*[Exchange with Yale College.]*

**[illegible] Croatia.** Fell at [illegible] p. m. [illegible] 4411.

[illegible] no crust. Shows grains [illegible]

*[illegible] Prof. C. U. Shepard.]*

**[illegible]na.** Fell March 25, 18[illegible]

[illegible] 1846, [2], [illegible] pp. [illegible]

[illegible] Chem. Pharm., 18[illegible]

[illegible] [2], xix, pp. [illegible]

[illegible] pp. 1[illegible]

[illegible] Akad., 187[illegible], pp. [illegible]

[illegible] 1883, [3], xxv[illegible]

[illegible] Zool., 188[illegible] x, [illegible]

[illegible] der Meteoriten [illegible] Akad., 188[illegible] lxxx[illegible]

[illegible] of small fragments [illegible] ments of the crust. [illegible] from this meteorite [illegible] two are [illegible] of sulphur with other [illegible] has aroused much [illegible] investigated the mete[illegible] opinion seems to be that chladnite is similar to enstatite. But Wadsworth says; "Chladnite ought no longer to be regarded as enstatite of the purest kind, as stated in most mineralogies, but rather as a mineral aggregate of which enstatite, feldspar and augite are the principal constituents.

Weight 2.49 grams.

[*By exchange with Prof. C. U. Shepard.*]

No. 21. **Sevier County, Tennessee.** Found in 1845. Museum number, 3346.

Iron. Irregular rusted fragment of nickeliferous iron. This meteorite is supposed to be identical with the one which was described in 1840 from Crosby's Creek, Cocke Co., Tennessee. Other specimens contain nodules of graphite. Weight 46.5 grams.

[*By exchange with J. L. Smith.*]

No. 22. **Hartford, Linn Co., Iowa.** Fell at 2:45 p. m., Feb. 25, 1847. Museum number, 3761.

C. U. Shepard; Am. Jour. Sci., 1847, [2], iv, pp. 288–289; 1848, [2], vi, pp. 403–405.

C. Rammelsberg; Monatsber. Ak. Wiss. Berlin, 1870, lxx, pp. 457–459.

Stone. With light gray groundmass showing chondritic structure, and with numerous grains of iron, some of them quite large. One face polished. Two of the edges show a dull black earthy crust.

Shepard remarks; "The most remarkable feature of the Iowa stone, however, consists in the homogeneousness of its earthy composition. It appears to contain but a single mineral species of this description, and this one which, though perhaps the most common in other meteoric stones, has until now escaped a separate recognition. I have therefore ventured to bestow upon it a distinct name, that of *howardite*." Rammelsberg later found that howardite was mainly a mixture of olivine and bronzite.

Weight 21 grams.

[*By exchange with Prof. C. U. Shepard.*]

No. 23. **Murfreesboro, Rutherford Co., Tennessee.** Found in 1847. Museum number, 3355.

G. Troost; Am. Jour. Sci., 1848, [2]. v. pp. 351–352.

Iron. Slab with one face polished and etched. Shows typical Widmannstättian figures. Weight 66.5 grams.

[*By exchange with Prof. J. L. Smith.*]

No. 24. **Monroe, Cabarras Co., North Carolina.** Fell at 3 p. m., Oct. 31, 1849. Museum number, 4698.

Iron. Specimen with three cut faces at right angles, to each other. These faces are polished and two of them show Widmannstättian figures. Weight, 193.5 grams.

[*By exchange with Prof. J. L. Smith.*]

No. 18. **Magura, Szlanicza, Arva, Hungary.** Found in 1840. Museum number, 4123.

A. Loewe; Neues Jahrb. Min., 1849, p. 199.

C. Bergmann; Ann. Physik. Chemie, 1857, pp. 256-260.

A. W. Wright; Am. Jour. Sci., 1875, [3], ix, pp. 294-302.

Iron. Irregular specimen with one face polished, another showing the crust. Largely made up of bright nickeliferous iron. Weight, 23 grams.

[*By exchange with Yale College.*]

No. 19. **Pusinsko Selo, Milena, Croatia.** Fell at 3 p. m., April 26, 1842. Museum number, 4411.

Stone. Light gray fragment with no crust. Shows grains of iron. Weight, 2.51 grams.

[*By exchange with Prof. C. U. Shepard.*]

No. 20. **Bishopville, South Carolina.** Fell March 25, 1843. Museum number, 4699.

C. U. Shepard; Am. Jour. Sci., 1846, [2], ii, pp. 379-381; 1848, [2], vi, pp. 411-414.

W. S. von Walterhausen; Ann. Chem. Pharm., 1851, lxxix, pp. 369–374.

J. L. Smith; Am. Jour. Sci., 1855, [2], xix, pp. 162–163; 1864, [2], xxxviii, pp. 225–226.

G. Rose; Abh. Berlin. Akad., 1863, pp. 117–122.

C. Rammelsberg; Abh. Berlin. Akad., 1870, pp. 121–123.

M. E. Wadsworth; Am. Jour. Sci., 1883, [3], xxvi, pp. 32–36, 248.—Mem. Mus. Comp. Zool., 1884, xi, pt. 1, pp. 199–201.

G. Tschermak; Die Mikros. Besch. der Meteoriten, 1883, i, pp. 9, 10.—Sitz. Wien. Akad., 1883, lxxxviii, [1], pp. 363–365.

Stone. White and gray. A number of small fragments and some powder; also a few fragments of the crust.

In 1846, Shepard described three new minerals from this meteorite,—chladnite, idiolite and apatoid. The last two are usually considered as easily decomposable compounds of sulphur with other elements of the stone. The silicate, chladnite, has aroused much discussion, and several mineralogists have investigated the meteorite because of this mineral. The general opinion seems to be that chladnite is similar to enstatite. But Wadsworth says; "Chladnite ought no longer to be regarded as enstatite of the purest kind, as stated in most mineralogies, but rather as a mineral aggregate of which enstatite, feldspar and augite are the principal constituents.

Weight 2.49 grams.

[*By exchange with Prof. C. U. Shepard.*]

No. 21. **Sevier County, Tennessee.** Found in 1845. Museum number, 3346.

Iron. Irregular rusted fragment of nickeliferous iron. This meteorite is supposed to be identical with the one which was described in 1840 from Crosby's Creek, Cocke Co., Tennessee. Other specimens contain nodules of graphite. Weight 46.5 grams.

[*By exchange with J. L. Smith.*]

No. 22. **Hartford, Linn Co., Iowa.** Fell at 2:45 p. m., Feb. 25, 1847. Museum number, 3761.

C. U. Shepard; Am. Jour. Sci., 1847, [2], iv, pp. 288–289; 1848, [2], vi, pp. 403–405.

C. Rammelsberg; Monatsber. Ak. Wiss. Berlin, 1870, lxx, pp. 457–459.

Stone. With light gray groundmass showing chondritic structure, and with numerous grains of iron, some of them quite large. One face polished. Two of the edges show a dull black earthy crust.

Shepard remarks; "The most remarkable feature of the Iowa stone, however, consists in the homogeneousness of its earthy composition. It appears to contain but a single mineral species of this description, and this one which, though perhaps the most common in other meteoric stones, has until now escaped a separate recognition. I have therefore ventured to bestow upon it a distinct name, that of *howardite.*" Rammelsberg later found that howardite was mainly a mixture of olivine and bronzite.

Weight 21 grams.

[*By exchange with Prof. C. U. Shepard.*]

No. 23. **Murfreesboro, Rutherford Co., Tennessee.** Found in 1847. Museum number, 3355.

G. Troost; Am. Jour. Sci., 1848, [2]. v. pp. 351–352.

Iron. Slab with one face polished and etched. Shows typical Widmannstättian figures. Weight 66.5 grams.

[*By exchange with Prof. J. L. Smith.*]

No. 24. **Monroe, Cabarras Co., North Carolina.** Fell at 3 p. m., Oct. 31, 1849. Museum number, 4698.

J. H. Gibbon; Am. Jour. Sci., 1850, [2], ix, pp. 143–146.
C. U. Shepard; Proc. Am. Assoc. Adv. Sci., 1850, iii, pp. 149–152.

Stone. Small fragment without any crust. Dark gray with light grains, and thickly sprinkled with iron. Weight 3.1 grams.

[*By exchange with Prof. C. U. Shepard.*]

No. 25. **Union County, Georgia.** Found in 1853. Museum number, 4414.

Iron. Small fragments, much rusted. Weight, 0.63 gram.

[*By exchange with Prof. C. U. Shepard.*]

No. 26. **Sarepta, Saratov, Russia.** Found in 1854. Museum number, 4413.

J. Auerbach; Sitz. Wien Akad., 1864, xlix, [2], p. 497.

Iron. Cuttings. Weight, 2.5 grams.

[*By exchange with Prof. C. U. Shepard.*]

No. 27. **Cranbourne, near Melbourne, Victoria, S. Australia.** Found in 1854, Museum number, 3341.

W. Haidinger; Sitz. Akad. Wiss., xliv, April 18, June 6, and Oct. 17, 1861; xlv, Jan. 9, 1862.
Walter Flight; Phil. Trans., 1882.—Chapter in the history of meteorites, 1887, pp. 174-181.

*a.* Iron. Rough fragment, almost silver-gray in color. Weight, 3.9 grams.

*b.* Another similar fragment. Weight, 3.5 grams.

*c.* Fifteen smaller pieces. Weight, 4.08 grams.

"This meteorite contains many nodules of troilite lying here and there amongst the plates and crystals of nickel-iron, always in rounded masses, only very occasionally an ill-defined cleavage plane being met with. They vary in size from half an inch to more than two inches in length, are usually covered with a thin layer of graphite, sometimes with some daubreelite surrounding them; and one nodule, consisting of graphite, was found to inclose troilite, which had aggregated inside the graphite in a curious way, so that the section of the nodule suggested the outline of a holly-leaf. * * * * Graphite occurs occasionally, but rarely, as nodules; sometimes as nodules inclosing troilite, like the one already referred to; sometimes in large sheet-like masses, in one case about four inches in length and two inches wide. (*Walter Flight.*)

[*By exchange with Prof. J. L. Smith.*]

No. 28. **Pernallee, Madura District, Madras, India.** Fell at noon, Feb. 28, 1857. Museum number, 4124.

E. Pfeiffer; Sitz. Wien Akad., 1863, xlvii, [2], pp. 460-463.
S. Meunier; Compt. rend., 1871, lxxiii, p. 346.

Stone. Dark gray, with large white, dark-gray and brown grains. Dull black crust and polished face, showing specks of iron distributed through the mass.

"Its structure has been described as pisolitic: Meunier, on the contrary, likens it to a coarsely granular grit. The grains composing it are often angular, sometimes more or less rounded, and in each instance have the characters of fragments which have been detached from larger masses: the rock, in short, is a breccia. During a careful examination of its four specimens preserved in the Paris collection, Meunier noted the presence of twelve distinct species of grains. * * * * * The presence, says the author, in the 'polygenic conglomerate' of Parnallee of fragments belonging to seven types at least of distinct meteoric rocks, demonstrates the co-existence of these types in the star-mass whence this Indian meteorite came." (Walter Flight.) Weight, 8 grams.

[*By exchange with Yale College.*]

No. 29. **Trenton, Washington County, Wisconsin.** Found in 1858. Museum number, 3360.

J. L. Smith; Am. Jour. Sci., 1869, [2], xlvii, pp. 271 272.

Fr. Brenndecke; Ann. Rep. Smithsonian Inst. for 1869, 1871, pp. 417-419.

J. A. Lapham; Am. Jour. Sci., 1872, [3], iii, p. 69.

Iron. Slab with one of the edges showing crust. One face has been polished and etched and now shows very well marked Widmannstättian figures; it also shows what Prof. Smith called "Laphamite markings." These he figured, and described as follows:

"A polished surface when etched gives well marked Widmannstättian figures. There is something, however, peculiar about the markings on this iron, which is doubtless common to other irons, but which has heretofore escaped my observation, and I cannot discover, in a hasty investigation, that it has been noticed by others. My attention was called to this peculiarity by Mr. Lapham, on a slice of the meteorite sent him etched; should these markings be entitled to a separate notice, I propose calling them *Laphamite markings.* The little drawing accompanying this, which is on a somewhat exaggerated scale, will show what they are. The Widmannstättian figures are *a*, bright metallic, with convex ends and sides; *b c*, of a darker color, are the other markings, usually smaller and with the sides and ends concave. The material of which these dark figures are composed, seems to have enveloped the lighter colored portion, which serves to make the dark lines so beautifully conspicuous. A good pocket glass will show that the darker figures are striated, with lines at nearly right angles to the bounding surfaces. When the figure is nearly square, the lines extend from each of the four sides, but when much enlongated, as at c, they are parallel with the longer sides. Often these lines do not reach the middle of the figure, where only a confused crystallization can be detected. In the interior of the enlongated figures, the lines are quite irregular, often running together, and showing a striking resemblance to woody fibre. The nature of these markings may be readily understood. They indicate the axes of minute columnar crystals, which tend to assume a position at right angles to the surface of cooling." The specimens in the museum shows markings that answer well to the above description and to the figure mentioned.

Weight, 180 Grams.

[*By exchange with Prof. J. L. Smith.*]

No. 30. **Staunton, Augusta County, Virginia.** Found in 1858. Museum number 4120.

J. W. Mallet; Am. Jour. Sci., 1871, [3], ii, pp. 10-15; 1878, [3], xv, pp. 337-338.—Brit. Assoc. Report (Brighton), 1872, p. 77.—Proc. Royal Soc., xx, p. 365.—Pogg. Ann., cxlvii, p. 134.

Iron. Slab, with one face etched, showing well marked Widmannstättian figures. Edges with crust. Mallet made four analyses of different pieces of this meteorite and each time found a very small percentage of tin. Weight 90 grams.

[*By exchange with Yale College.*]

No. 31. **Coopertown, Robertson County, Tennessee.** Known in 1860. Museum number 3356.

J. L. Smith; Am. Jour. Sci., 1861, [2], xxxi, p 266.

Iron. Slab with both faces polished; one showing very large Widmannstättian figures distinctly, the other in distinctly. Weight 94 grams.

[*By exchange with Prof. J. L. Smith.*]

No. 32. **Orgueil, Tarn-et-Garonne, France.** Fell at 8 p. m., May 14, 1864. Museum number 3340.

S. Cloez; Comptes Rendus, 1864, lix, pp. 37-40.

F. Pisini; Comptes Rendus, 1864, lix, pp. 132-135.

Stone. No iron. Dead black with white specks and dull black crust. Weight, 1.683 grams.

[*By exchange with Prof. J. L. Smith.*]

No. 33. **Bonanza, Coahuila, Mexico.** Found in 1865. Museum number, 3758.

C. U. Shepard; Am. Jour Sci., 1867, [2], xliii, pp. 384-385.

Iron. Irregular fragment, three of whose faces are polished. Two of these have been partially etched and show Widmannstättian figures rather indistinctly. Weight, 39.8 grams.

[*By exchange with Prof. C. U. Shepard.*]

No. 34. **Knyahinya Unghvar, Hungary.** Fell at 5 p. m., June 9, 1866. Museum numbers, 3350(*a*) and 3760(*b*).

A. Kenngott; Sitzber. Ak. Wiss. Wien, 1869, lix, p. 873. —Phil. Mag., 1869, xxxvii, p. 424.

J. V. Schiaparelli; Entwurf einer astronomischen Theorie der Sternschnuppen, 1871, Stettin: Nahmer., p. 267.

E. H. von Baumhauer; Archives Néerlandaises, 1872, vii, p. 146.

W. von Haidinger; Sitzber. Ak. Wiss. Wien, liv. 200 and 513.

G. Rose; Monatsber. Ak. Wiss. Berlin, lxvii, p. 203.

*a*. Stone. One face polished showing light and dark colored chondri and specks of iron. Three of the faces are covered with a dark crust. A fifth shows a broken surface with the iron rusted.

> "It is computed that over a limited area more than a thousand stones, weighing in all from 8 to 10 cwt., must have fallen. The largest found is now preserved in the Vienna collection; it weighs 293.3 kilog. (5 cwt. 3 qrs. 3 lbs.), and measures 2 ft. 4 in. long and 18 in. broad, and penetrated the ground to a depth of 11 feet. * * * * * To the naked eye the section appears to be finely granular and of a gray tint, and even with a very moderate power is seen to present spherular structure, recalling, if relative size be left out of consideration, that of the globular diorite of Corsica. The opaque ingredients are nickel-iron, troilite and a black substance; in addition to these are two crystalline mineral species, the one colorless and transparent and somewhat fissured, the other gray and translucent and presenting an appearance of lamellar structure; both appear in angular and rounded granules, and both are bi-refractive; they are differently affected by hydrochloric acid, and from other differences in their crystalline characters it may be inferred that the gray silicate is an enstatite, the colorless silicate is olivine.*

Weight, 14 grams.

[*By exchange with Prof. J. L. Smith.*]

*b*. Stone. Bluish gray, with grains of iron sprinkled through it, in some places in groups. Weight, 5.82 grams.

[*By exchange with Prof. C. U. Shepard.*]

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*Walter Flight; a Chapter in the History of Meteorites, p. 145.

No. 35. **Bear Creek, Denver Co., Colorado.** Found in 1866. Museum number, 4691.

C. U. Shepard; Am. Jour. Sci., 1866, [2], xlii, pp. 250–251.

J. Henry; Am. Jour. Sci., 1866, [2], xlii, pp. 286–287.

J. L. Smith; Am. Jour. Sci., 1867, [2], xliii, pp. 66-67.

C. T. Jackson; Am. Jour. Sci., 1867, [2], xliii, pp. 280-281.

Iron. Irregular fragment with one face cut. Very coarsely crystalline. Called the Aeritopos meteorite by Prof. Shepard. Weight, 41.5 grams.

[*By exchange with Prof. C. U. Shepard.*]

No. 36. **Auburn, Macon Co., Alabama.** Found in 1867. Museum number, 4417.

C. U. Shepard; Am. Jour. Sci., 1869, [2], xlvii., pp. 230-233.

J. L. Smith; Am. Jour. Sci., 1870, [2], xlix, p. 331.

Iron. Irregular fragment, much rusted, and one side partially polished. The meteorite seems to be made up of a mass of granular concretions. After polishing a face of this meteorite Prof. Shepard says:

> "The face, on being subject to the action of dilute nitric acid, gave me a series of markings altogether new. They are extremely fine and delicate in their dimensions, and require a strong light with the aid of a microscope to be seen with distinctness. The first character that displays itself is somewhat that of a mesh or network, and arises from the polygonal boundaries of the granular concretions. The areas within these lines or edges (which are exceedingly thin) have a glittering luster when held at a fixed angle to the light, though this angle often varies for different concretions, as in the case of a polished surface of coarse grained calcite or fluor. The second character that arrests attention in examination, is the finely striated surface of each concretion,—one set of lines being perfectly straight and equi-distant, as in calcite and labradorite, while a second set, but less distinct, cross these at right angles. The final peculiarity of the markings consists in this,—that these fine striæ are wholly made up of dots or beads, which are arranged in almost absolute contact, and are therefore to be regarded as consisting wholly of sections of rhabdite needles, while on the other hand, the mesh-like markings, first noticed, are composed of plates of schreibersite."

Weight, 24.92 grams.

[*By exchange with Prof. C. U. Shepard.*]

No. 37. **Pultusk, Sielce Nowy, Poland.** Fell at 7 p. m., Jan. 30, 1868. Museum numbers, 3352 (*c*), 3759 (*a*) and 4121(*b*).

G. Werther; Schrift. Konigsberg Gessel., 1868, ix, pp. 35-40.

G. vom Rath; Neues Jahrb. Min., 1869, pp. 80-82.

C. Rammelsberg; Mon. Berlin Akad., 1870, pp. 448-452.

*a*. Stone. One face polished, showing numerous glistening iron grains. The rest of the specimen is covered by a dull, brown crust. Weight, 100 grams.

[*By exchange with Prof. C. U. Shepard.*]

*b*. Part of a smaller individual with one side polished, the others showing crust. Weight, 11 grams.

[*By exchange with Yale College.*]

*c*. Part of a still smaller individual; one side polished and the others mostly covered with crust. Weight, 7.5 grams.

[*By exchange with Prof. J. L. Smith.*]

No. 38. **Ovifak, Island of Disko, Greenland.** Found in 1870. Museum numbers, 3345 (*a* and *b*) and 4412 (*c*).

A. E. Nordenskjöld; K. Vet-Akad. Förh., 1870, p. 873; (see translation in Geological Magazine, 1872, [1], ix, p. 518.)

J. Lorenzen; Zeit. Deut. Geol. Gesell., 1883, xxxv, pp. 695-703.

G. A. Daubrée; Compt. rend., 1877, lxxxiv, p. 66; lxxxvii, p. 911.

J. L. Smith, Ann. Chemie. Phys., 1879, [5], xvi, pp. 452-505.

*a*. Native iron, formerly supposed to be of meteoric origin. Taken from basaltic rocks. Irregular, much rusted, piece appearing somewhat granular. Weight, 430 grams.

[*By exchange with Prof. J. L. Smith.*]

*b*. A small slab of the same, polished on both sides. Weight, 45 grams.

[*By exchange with Prof. J. L. Smith.*]

*c*. Fragment of the same, much rusted. Weight, 14.5 grams.

[*By exchange with Prof. C. U. Shepard.*]

No. 39. **Searsmont, Waldo Co., Maine.** Fell at 8:15 a. m., May 21, 1871. Museum number, 4409.

C. U. Shepard; Am. Jour. Sci., 1871, [3], ii, p. 133.

J. L. Smith; Am. Jour. Sci., 1871, [3], ii, pp. 200-201.

*a*. Stone. Gray and crumbling. One side shows a black spongy crust which is much thicker than the crust usually seen on meteorites. Weight, 0.83 gram *b*. Smaller fragment, also showing crust on one side. Weight, 0.5 gram.

[*By exchange with Prof. C. U. Shepard.*]

No. 40. **Waconda, Mitchell Co., Kansas.** Found in 1874. Museum number, 3342, (*a*) and 3762 (*b*).

C. U. Shepard; Am Jour. Sci-, 1876, [3], xi, pp. 473-474.

J. L. Smith; Am. Jour. Sci., 1877, [3], xiii, pp. 211-213.

*a*. Stone. Light gray, friable, clay-like mass containing very little iron. One side with a dull black crust. Weight, 72 gram.

[*By exchange with Prof. J. L. Smith.*]

*b*. Stone. Light gray fragment without crust. One face polished, showing considerable iron in two places. Weight, 72 grams.

[*By exchange with Prof. C. U. Shepard.*]

No. 41. **Mejillones, near the Desert of Atacama, South America.** Found in 1874. Museum number, 4695.

Iron. Small pieces of cut slab.

[*By exchange with Prof. C. U. Shepard.*]

No. 42. **Butler, Bates County, Missouri.** Found in 1874. Musenm number, 3357.

G. C. Broadhead; Am. Jour. Sci., 1875, [3], x, p. 401.

J. L. Smith; Am. Jour. Sci., 1877, [3], xiii, p. 213.

A. Brezina; Sitz. Akad. Wiss., 1880, lxxxii, Oct. Heft.

Iron. Thin slab with one face polished and etched, showing large and well marked Widmannstättian figures. The specimen contains a small nodule of triolite.

> "It was noticed that the greater part of the iron had an even dull appearance, but in this lustreless iron gray part lay numerous—in part individual, in part grouped together—lamellæ, of which four differently directed systems appear on the sections. The lamellæ together form a skeleton—an octahedral skeleton. The groundmass, though lustreless and structureless, shows a peculiar play of light; its hardness is remarkably low, a little below 4, being distinctly scratchd by fluor."*

Weight, 104 grams.

[*By exchange with Prof. J. L. Smith.*]

No. 43. **Iowa County, Iowa.** Fell at 10:30 p. m., Feb. 12, 1875. Museum number, 3359.

A. W. Wright; Am. Jour. Sci., 1875, [3], ix, pp. 459-460; 1875, [3], x, pp. 44-49.

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*Walter Flight; A Chapter in the History of Meteorites, p. 187.

N. R Leonard; Am. Jour. Sci., 1875,[3], x, pp. 357-363,
J. L. Smith; Am. Jour. Sci., 1875,[3], x, pp. 362-363.
C. W. Irish; An Account of the Detonating Meteor of Feb. 12, 1875, Daily Press Job Printing Office, Iowa City.
G. A. Daubrée; L'Institut, 1875, (Nos. 105-122), p. 38.
C. W. Gümbel; Sitzungsber. Wiss. München, 1845, v. p. 313.

Stone. A complete individual, in the form of a parallelogram, 3 inches by 2½ and 1 inch where thickest. Nearly completely covered with a dull black crust, some of the fractures showing crust partially formed. One end cut, showing compact, rather dark gray stony substance with many iron grains sprinkled through it. Similar in appearance to the Pultusk and to the more recent Winnebago meteorites.

Weight, 306.66 grams,

[*By exchange with Prof. J. L. Smith.*]

No. 44. **Santa Catarina, Rio San Francisco do Sul, Brazil.** Known in 1875. Museum numbers 4415(*a*) and 4692(*b*).

Guignet and Almeida; Comptes Rendus, 1876, lxxxiii, pp. 917-919.

*a*. Iron. A small fragment with one side polished. Weight, 18.35 grams.

*b*. A smaller fragment of the same. Weight 7.071 grams.

[*By exchange with Prof. J. L. Smith.*]

No. 45. **Warrenton, Warren County, Missouri.** Fell Jan. 3, 1877. Museum number, 3347.

J. L. Smith; Am. Jour. Sci., 1877,[3], xiii, p. 243; 1877, [3], xiv, pp. 222-224.

*a*. Stone. Bluish-gray, soft, clay-like mass, with very little iron. A spongy blue-black crust on one side.

Weight, 13 grams.

*b*. Similar fragment, showing a small area of crust.
Weight, 9.5 grams.

*c*. A smaller fragment. No crust. Weight, 5 grams.

[*By exchange with Prof. J. L. Smith.*]

No. 46. **Cynthiana, Harrison County, Kentucky.** Fell at 4 p. m. Jan. 23, 1877. Museum number, 3343.

J. L. Smith; Am. Jour. Sci., 1877,[3], xiii, p. 243; 1877, [3], xiv, pp. 224-227.

*a*. Stone. Dull gray, with white grains and some iron particles. One side with a dull black crust partially full of pittings. Another side polished. Weight, 31.5 grams.

*b*. Smaller fragment of the same, showing crust on one side. Weight, 8 grams.

[*By exchange with Prof. J. L. Smith.*]

No. 47. **Sarbanovac, Soko-Banjia Alexinatz, Servia.** Fell at 2 p. m., Oct. 13, 1877. Museum number, 4407.

E. Döll; Verhandl. d. K. K. Geol. Gesell., 1877, No. 16, p. 283.

S. M. Losanitch; Berichte d. Deut. Chem. Gessel., 1878, xi, p. 96.

Stone. Light gray fragment, with dark gray grains and some iron particles. No crust. Weight, 1.75 grams.

[*By exchange with Prof. C. U. Shepard.*]

No. 48. **Casey County, Georgia.** Found in 1877. Museum number, 3354.

A. Brezina; Stizber. Akad. Wiss., 1880, lxxxii, Oct. part.

Iron. Thin slab with one side polished and etched, but showing no Widmanstättian figures. Weight 36.5 grams.

[*By exchange with Prof. J. L. Smith.*]

No. 49. **Estherville, Emmet County, Iowa.** [**"The Perry Meteor."**] Fell at 5 p. m., May 10, 1879. Museum numbers, 3058 (*a* to *e*), 4125 (*f*) and 4128 (*g*).

S.F. Peckham; Am. Jour. Sci., 1879 [3], xviii, pp. 77-78.

C. U. Shepard; Am. Jour. Sci., 1879 [3], xviii, pp. 186-188.

J. L. Smith; Am. Jour Sci., 1880, [3], xix, pp. 459-463, 495. (Prof. Smith's account was also published in the Eighth Annual Report of the Geol. and Nat. Hist. Survey of Minn., pp. 176-180.)

S. Meunier; Comptes Rendus, 1882, xciv, pp. 1659-1661.

M. E. Wadsworth; Mem. Mus. Comp. Zool., 1884, vol. xi, pt. I, pp. 97-101.

*a*. This is the second largest of the pieces that have been found. It was discovered two miles west of the largest piece, which weighed 437 pounds, and originally weighed 170 pounds.

"The masses are rough and knotted like large mulberry calculi, with rounded protuberances projecting from the surface on every side; the black coating is not uniform, being most marked between the projections. These projections have sometimes a bright metallic surface, showing them to consist of nodules of iron; and they also contain lumps of an olive-green mineral, having a distinct and easy cleavage. The greater portion of the stony material is of a gray color, with this green mineral irregularly distributed through it. * * * * * * The masses are quite heavy and vary much in specific gravity in their different parts; but the average can not be less than 4.5. When broken one is immediately struck with the large nodules of metal among the gray and the green stony substances, some of which will weigh 100 grams or more. In this respect the meteorite is unique, it differing entirely from the mixed meteorites of Pallas, Atacama, etc., or the known meteoric stones rich in iron; for in none of these has the iron this nodular character. * * * * * The constitution of this meteorite, so far as I have been able to make it out, is therefore as follows: Bronzite, abundant; olivine, abundant; nickeliferous iron, abundant; troilite in moderate quantity; chromite, in minute quantity; silicate, not yet well determined."* This specimen is a large irregular mass, much rusted, and one end has been sawed off leaving a polished surface.

Weight, 60,210 grams (132¾ pounds.)

[*Purchased for the Museum by Prof. E. J. Thompson*]

*b.* Rough irregular pieces. Two sides are cut; another shows crust. Weight, 215 grams.

[*Purchased by for the Museum Prof. E. J. Thompson.*]

*c.* Irregular piece, one side cut. Weight, 41 grams.

[*Purchased for the Museum by Prof. E. J. Thompson.*]

*d.* Irregular ragged piece, one side cut. Weight, 19.5 grams.

[*Purchased for the Museum by Prof. E. J. Thompson.*]

*e.* Rough ragged fragment. Weight 19.2 grams.

[*Purchased for the Museum by Prof. E. J. Thompson.*]

*f.* Small irregular piece of one of the iron nodules. One side polished and etched, showing Widmannstättian figures. Weight, 8 grams.

[*Presented by Prof. C. W. Hall.*]

*g.* Small fragments of peckhamite from the above meteorite. Weight 0.672 gram.

[*Purchased probably from Prof. J. L. Smith.*]

No. 50. **Lexington Co., South Carolina.** Found in May, 1880. Museum number, 4418.

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*Am. Jour. Sci., 1880, [3], xix. This silicate is probably peckhamite.

C. U. Shepard; Am. Jour. Sci., 1881, [3], xxi, pp. 117–119.

Iron. Irregular fragment with three faces polished. One of them is etched, but shows Widmannstättian figures only indistinctly. Weight, 17.5 grams.

[*By exchange with Prof. C. U. Shepard.*]

No. 51. **Ivanpah, San Bernadino Co., California.** Found in 1880. Museum numbers, 4420 (*b*) and 4421 (*a*).

C. U. Shepard; Am. Jour. Sci., 1880, [3], xix, pp. 381–382.

*a*. Iron. Cuttings. Weight, 2.3 grams.

*b*. Small irregular fragment of iron. Weight, 1.98 grams.

[*By exchange with Prof. C. U. Shepard.*]

No. 52. **Brenham, Kiowa Co., Kansas.** Found in 1885. Museum number, 7240.

N. H. Winchell and J. A. Dodge; Amer. Geologist, 1890, v, pp. 309–312; 1890, vi, pp. 370–377.

G. F. Kunz; Science, 1890, xv, p. 359.—Trans. N. Y. Acad. Sci., 1890, ix, pp. 186–194.

*a*. Iron. A coarse, metallic sponge containing olivine, chromite and troilite.

"Metallic iron comprises somewhat less than one-half the meteorite, and it serves as a matrix in which are embraced amygdaloidal or roundish masses from the size of a pea to that of a musket ball, and larger, of the black and yellowish minerals which comprise nearly the whole of the rest of the mass." This mass originally weighed 211 pounds. "It was approximately globular, with a broad shallow depression that encircled it about half way. Its exterior is oxidized by long exposure, some of the mineral grains having been profoundly affected by the penetration of iron oxide." About 85 pounds have been cut off from one side of the mass, leaving a plane surface which has been figured in the American Geologist, vol. vi, plate vii.

Weight, 55,790 grams (123 pounds).

*b*. Slab cut from the above mass, about one inch thick and 42 inches in circumference. Weight, 9410 grams.

Shown in plate vii, vol. vi, Dec., 1890, of the American Geologist.

*c*. Irregular mass with two sides polished; one has been etched and shows Widmannstättian figures; this surface also is figured in the American Geologist, vol. vi, p. 272. Weight, 2648 grams.

*k*. Wedge-shaped piece. 3½ inches long, 1½ wide and 2½ thick at the large end. All the faces cut except one, which is the largest and is covered by crust. Weight, 630 grams.

*l.* Irregular piece, with three sides cut, one partially cut, and the other with crust. Contains a large proportion of the black minerals. Weight, 630 grams.

*m.* Irregularly rectangular piece. Four faces cut; another shows crust. About 2½ inches by 2 by 1½. Weight, 570 grams.

*p.* Irregular ragged piece of metallic sponge. Most of the olivine has fallen out, but there is considerable of the black minerals present. Weight, 100 grams.

*q.* Ragged fragment, having some iron and considerable of black minerals. Weight, 28 grams.

*r.* Ragged fragment. There is considerable olivine and a small amount of the black minerals present. Weight, 17.7 grams.

*s.* Rusted, ragged fragment with considerable olivine. Weight, 12.7 grams.

*t.* Irregular fragment with a small amount of the black minerals and no olivine. Weight, 12 grams.

*u.* Ragged fragment; a small amount of the black minerals, but no olivine present. Weight, 11.8 grams.

*v.* Irregular fragment with considerable of the black minerals but no olivine. Weight, 11.3 grams.

*w.* Ragged sponge of iron containing nothing else. Weight, 9.6 grams.

*x.* Irregular rusted spongy fragment, having a little olivine. Weight, 9.1 grams.

*y.* Ragged fragment of iron containing nothing else. Weight, 8.9 grams.

*z.* Ragged fragment with considerable of the black minerals and very little olivine. Weight, 8.7 grams.

*aa.* Ragged, rusted fragment, Weight, 7.4 grams.

*ab.* Coarse cuttings, mostly iron. Weight about 4000 grams

*ac.* Finer cuttings. Weight, 1100 grams.

*ad.* Finest cuttings. Weight about 5500 grams.

No. 53. **Bandera Co., Texas. [Pipe Creek Meteorite.]** Found in 1887. Museum number, 7242.

A. R. Ledoux; Trans, N. Y. Acad. Sci., 1889, viii, pp. 186-187.

Stone. Slab, one fourth inch thick and five inches in circumference; both faces and two edges have been polished. Dark brown apparently porous groundmass holding black grains and irregular shining iron particles. Weight, 24.6 grams.

[*By exchange with Dr. H. Hensoldt.*]

No. 54. **Winnebago County, Iowa.** Fell at 5.15 p. m., May 2, 1890. Museum number, 7239.

G. F. Kunz; Trans. N. Y. Acad. Sci., 1890, ix, pp. 201-203.

J. Torrey and E. H. Barbour; Amer. Geologist, 1891, viii, pp. 67-72.

*a.* Stone. Large individual measuring about 13 inches in greatest diameter, and about 9 inches in the other directions. Covered by crust, except where it has been somewhat broken along the edges, and an area 7 by 3 inches on one side, from which a piece of the stone, not more than an inch thick, has been broken off. This is the 66-pound stone figured in the American Geologist, vol. viii, p. 68.

"This meteor is a typical chondrite, apparently of the type of the Parnallite group of Meunier, which fell February 28th, 1857, at Parnellee, India. The stone is porous, and when placed in water to ascertain its specific gravity, there is a considerable ebullition of air. The specific gravity on a fifteen-gram piece, was found to be 3.638. The crust is rather thin, opaque black, not shining, and, under the microscope is very scorious, resembling the Knyahinya (Hungary) and the West Liberty (Iowa) meteoric stones. A broken surface shows the interior color to be gray spotted with brown, black and white, the latter showing the existence of small specks of meteoric iron from one to two millimetres across. Troilite is also present in small rounded masses of about the same size. On one broken surface was a very thin scum of a black substance, evidently graphite, soft enough to mark white paper; a feldspar (anorthite) was likewise observed, and enstatite was also present."* "The dead black scoriaceous crust when broken, reveals a light gray stone interspersed with innumerable dark particles of iron and globules of troilite, quite like the Iowa County stones in appearance. Thin seams and cracks occur occasionally filled with a substance that has somewhat the appearance of graphite, and small spheroidal masses of olivine are abundant."†

Weight, 29.820 grams (65.75 pounds.)

[*Purchased on the spot by H. V. Winchell, of the party on whose farm it fell.*]

*b.* Individual completely covered by crust. Weight, 961.5 grams.

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*Trans. N. Y. Acad. Sci., ix, p. 201.

† Amer. Geologist, viii, p. 67.

*c.* Fragment broken from the large individual (*a*). Shows a few minute dark veins or seams. About half the surface covered by crust. Weight, 450 grams.

*d.* Individual completely covered by crust, except a small area on one side. Weight, 75.8 grams.

*e.* Complete individual. Crust broken on edges in two or three places, and on one side it is thinner and rather glassy in appearance. Weight, 62.7 grams.

*f.* Individual completely covered by crust. Weight, 49.3 grams.

*g.* Irregular fragment. Two sides (or about half its surface) covered by crust. Weight, 48.6 grams.

*h.* Irregular individual completely covered by crust except where it has been broken off in a few places. Weight, 46.1 grams.

*i.* Roughly rectangular individual, about 1¾ inches by 1 by ¾; mostly covered by crust, but on one side the crust is imperfectly formed, as if a piece was here broken off a short time before striking the ground. One broken and partially polished. Weight, 45.3 grams.

*j.* Fragment more than half covered with crust. Weight, 40.5 grams.

*k.* Thin fragment about 2 inches long and 1¼ wide. Over half covered by crust. This is probably a piece from the large individual (*a*). Weight, 32.7 grams.

*l.* Complete individual. Weight, 31.8 grams.

*o.* Irregular piece covered by crust, except at one side, which is rusted. Another side has a comparatively thin crust. -Weight, 29.1 grams.

*r.* Individual. Small area of crust gone from one edge. Weight 20.4 grams.

*s* Complete individual. One end has a rough surface and thinner crust. Weight, 19.6 grams.

*t.* Small fragment from the large individual (*a*). Shows small area of crust. Weight, 18 grams.

*u.* Individual. Crust broken some on edges and thinner on one side, which has a rough surface. Weight 16.6 grams.

*v.* Complete individual. Weight 16.2 grams.

*x.* Individual. Crust spongy on one side. Weight 14.9 grams.

*y.* Fragment about half covered by crust. Weight 14.6 grams.

*ab*. Complete individual in the form of an irregular three-sided fragment, the base of which has a very spongy crust. Small pieces of the crust broken off in two or three places. Weight 12.3 grams.

*ac*. Fragment about half covered by crust; the part without crust is apparently somewhat rusted. Weight 11.7 grams.

*ad*. Apparently an individual with one end broken off. Weight 11.6 grams.

*ae*. Individual, crust gone from part of one side. Weight 10.5 grams.

*af*. Individual. One side is rough and has thinner crust. Crust cracked off somewhat on the edges. Weight 10.1 grams.

*ag*. Piece all covered with crust, excepting one end. Crust very thick. Weight, 8.8 grams.

*ah*. Individual. Two-thirds the surface is rough and has thinner crust. Weight, 8.6 grams.

*ai*. Irregular individual. Crust imperfectly formed on one side. Weight, 8.3 grams.

*aj*. Complete individual. Weight, 8.3 grams.

*ak*. Complete individual. Weight, 7.5 grams.

*am*. Complete indvidual. On one side the crust appears thin and very porous. Weight. 7.3 grams.

*an*. Irregular individual, with one side rough where the crust is thin. Weight, 7.1 grams.

*ao*. Complete individual. Weight, 7 grams.

*aq*. Fragment, one-third covered by crust. Weight, 6.7 grams.

*ar*. Piece about two-thirds covered by crust. Weight, 6.4 grams.

*at*. Individual with about one-third of the crust gone. Weight, 6 grams.

*au*. Individual with crust thin on one side. Crust broken off in a few places. Weight, 5.6 grams.

*av*. Irregular fragment nearly one-half covered by crust. Weight, 5.5 grams.

*aw*. Individual with small area of crust gone. Weight, 5.4 grams.

*ay*. Complete individual. Weight, 5.2 grams.

*az*. Individual with crust broken off in two places. One side rough and with thinner crust. Weight, 5.03 grams.

*ba*. Complete individual. Weight, 4.91 grams.

*bb*. Complete individual. Weight, 4.9 grams.
*bd*. Complete individual. Weight, 4.3 grams.
*be*. Complete individual. Weight, 4.3 grams.
*bg*. Complete individual. Weight, 4 grams.
*bi*. Complete individual. Small area of crust broken off. Weight, 3.6 grams.
*bj*. Piece covered by crust, except on one side. Weight, 3.4 grams.
*bk*. Complete individual. Weight, 3.3 grams.
*bm*. Individual with small area of crust broken off one end. Weight, 2.9 grams.
*bn*. Complete individual. Weight, 2.8 grams.
*bo*. Complete individual. Crust in places quite porous or spongy. Weight, 2.7 grams.
*bp*. Individual with crust broken off in several places. Weight, 2.7 grams.
*bq*. Fragment about one-third covered by crust. Weight, 2.4 grams.
*br*. Piece two-thirds covered by crust. Weight 2.2 grams.
*bs*. Complete individual. Weight, 2.2 grams.
*bt*. Irregular fragment about one-half covered by crust. Weight, 2.1 grams.
*bu*. Complete individual. Weight, 2.1 grams.
*bv*. Complete individual. Crust thinner on surface; rough on one side. Weight 2 grams.
*bw*. Complete individual. Weight 1.9 grams.
*bx*. Complete individual. Weight, 1.84 grams.
*by*. Individual with some of the crust gone from one edge. Weight, 1.78 grams.
*bz*. Complete individual. Weight, 1.72 grams.
*ca*. Complete individual. Weight, 1.66 grams.
*cb*. Individual with crust broken off in places from the edges. Weight, 1.56 grams.
*cc*. Complete individual. Weight, 1.54 grams.
*cd*. Small irregular fragment showing no crust. Weight, 1.53 grams.
*ce*. Piece two-thirds covered by crust. Weight, 1.51 grams.
*cf*. Complete individual. Weight, 1.45 grams.
*cg*. Complete individual. Weight, 1.3 grams.
*ch*. Complete individual with rough surface. Weight, 119 grams.
*ci*. Complete individual. Weight, 1.09 grams.
*cj*. Complete individual. Weight, 1.03 grams.

*ck.* Complete individual. Weight, 0.98 gram.

*cl.* Complete individual with quite porous or spongy crust. Weight, 0.96 gram.

*cm.* Individual. Crust quite thick, and a small area of it broken off one end. Weight, 0.87 gram.

*cn.* Fragment one-third covered by crust. Weight, 0.85 gram.

*co.* Complete individual. Weight, 0.75 gram.

*cp.* Complete individual. Weight, 0.55 gram.

*cq.* Irregular fragment without any crust. Weight, 0.37 gram.

[*Purchased on the spot by N. H. Winchell from parties who found them.*]

No. 55. **Washington County, Kansas.** Fell June 25, 1890. Museum number, 7241.

Stone. Dark ground mass with some white grains and glistening metallic particles. Very heavy and rich in iron. Weight, 562 grams.

[*Purchased through H. V. Winchell.*]

No. 56. **Diablo Canon, Arizona.** Found March, 1891. Museum number, 7947.

Iron. Entire individual. Lenticular mass. Weight 12¾ ounces. Some pieces contained diamonds.

[*By exchange with A. E. Foote.*]

No. 57. **Diablo Canon, Arizona.** Found March, 1891.

Siliceous iron associated with the last. Weight, 7¾ ounces. Museum number, 7948.

A. E. Foote; Am. Jour. Sci., vol. xlii, p. 413, 1891.

About 1700 pounds have been found. The diamonds were discovered in cutting, by Prof. G. A. Kœig.

No. 58. **Fayette County, Texas. (La Grange Meteorite.)** Found in 1878 by farmers, but brought to light by Mr. H. Hensoldt in 1888. Museum number, 7949.

Chondritic stone, slab, length 22 in., width 11 in., ⅞ in. thick, weight, 16 pounds. [*By exchange with Henry A. Ward.*]

Howell; Science, Feb. 3, 1888, p. 55. J. E. Whitfield and G. P. Merrill; Am. Jour, Sci., 1888 [3] vol. xxxvi, p. 113. Total weight about 146 kilos. * * *

"To the unaided eye the chondritic structure is not distinctly marked, a broken surface showing a fine grained and evidently crystalline-granular rock, very compact, of a greenish-gray color and thickly studded with small metallic points with a brassy lustre. A polished surface shows the stone to be composed of small chondri rarely over 2 mm. in diameter, thickly and firmly compacted in a fine granular groundmass. Throughout the entire mass are thickly distributed innumerable small irregular flecks of a steel-gray, brassy and bronze-yellow color, presumably native iron and pyrrhotite."

## VIII.

# NOTES ON THE PETROGRAPHY AND GEOLOGY OF THE AKELEY LAKE REGION, IN NORTHEASTERN MINNESOTA.

BY W. S. BAYLEY,

*U. S. Assistant Geologist, Lake Superior Division.*

Upon the request of the writer, a number of specimens of the rocks collected by members of the Minnesota Geological Survey from the region adjacent to Chub (Akeley) lake, in Sec. 29, T. 65 N., R. 4 W., Minn., were kindly furnished him for microscopic study by Prof. N. H. Winchell, State Geologist of Minnesota. At the time the request was made there was no intention of publishing the results of this study, but when the microscopical features of the different rocks were compared with each other, and with their structural relationships, it was discovered that an entirely new light was thrown on the latter, and that these must be given a different interpretation from that given them in the 16th and 17th Minnesota reports. Consequently, it has been thought wise by Prof. Winchell to make public what is now known concerning the rocks in this vicinity, in order that the geology outlined in the reports may be appreciated with a little more clearness than has heretofore been possible.

Since some of the conclusions reached by the Minnesota geologists, after study of the hand-specimens of these rocks, are here shown to be erroneous, in consequence of a mistaken supposition with reference to their nature, it would seem proper to emphasize once more the danger of generalizing concerning the relations of pre-Cambrian rocks before having subjected them to a thorough microscopical investigation.

I desire to thank Prof. Winchell for his courtesy in providing the material asked for, and for his kindness in affording this means for the publication of my article.

## (1) OCCURRENCE AND DESCRIPTION OF SPECIMENS MENTIONED IN THE 16TH REPORT.

1327. (16th Ann. Report, p. 80). South and a little east of the NW corner Sec. 24, T. 65 N., R. 4 W.

At this place is a low northward facing Animikie bluff in which the strata dip southeastwardly about 12°. It is made up of ore on top and of alternating gray grit and sandstone, with some ore and chert, below (1327).*

Under the microscope 1327 is seen to be a well defined quartzyte, composed of rounded quartz-grains, contiguous to some of which may be detected enlargements. The inclusions are fine dust-like particles and liquid enclosures. Between the quartz-grains was once an abundant cement, but this has been changed to a crystallized aggregate of fine needles of hornblende and fibres of chlorite, that often unite to form radiating spherulites, in the centers of some of which are little irregular masses of magnetite. These spherulites are scattered here and there along the lines separating adjacent quartz-grains. Occasionally they are confined entirely to these interstitial spaces, but more frequently their fibres penetrate the quartz-grains on both sides, while sometimes a spherulite may be entirely surrounded by quartz (Fig. 1). Were it not quite certain that the rock is fragmental, from the relations existing between the hornblende needles and the quartz, we would be led to regard the latter as

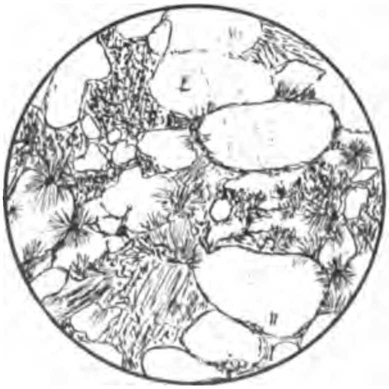

FIG. 1.
Fragmental quartzyte, with cementing material changed to chlorite and fibrous hornblende. No. 1327,x27.

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*The descriptions of occurrences are abstracted from the Minnesota reports, where they appear at greater lengths.

younger than the former. As the case stands, we must conclude that the spherulites have formed since the rock was laid down.

1329. (16th Ann. Report, pp. 81-82.) About 250 paces west of NE corner Sec. 22, T. 65 N., R. 4 W.

This specimen is a sample of a great dyke that cuts the gneiss underlying the rocks above mentioned. 1329 does not correctly represent the dyke, but it is the only sample that has been furnished. It is a very coarse-grained olivine-diabase, with long lath-shaped crystals of a plagioclase near andesine, large grains of light-colored olivine, and interstitial, allotriomorphic dark pink, slightly pleochroic augite, with much irregular magnetite in and around the augite. This last named mineral is quite fresh, except in small areas immediately next to feldspars, where it is slightly chloritized. The rock resembles very strongly the substance of the great dykes everywhere cutting the Animikie in the lake Superior region.

1334 and 1335. (16th Ann. Report, p. 83.) SW ¼ Sec. 21, T. 65 N., R. 4 W.

The greenstone represented by 1329 extends southward to near the south line of Sec. 21, where it is evident that the greenstone has given way to the Animikie carrying magnetite. The most southern identifiable portion of the greenstone is represented by 1334. Beyond this there is a transition to a rock represented by 1335, which is heavily bedded. It dips south at 45° and apparently underlies the iron beds (1336). The rock has not the characteristics of an eruptive, but it appears to have those of a basic sedimentary bed which has been metamorphosed. Such a rock has not before been seen in Minnesota. 1334 and 1335 occur in two bluffs on the opposite sides of a narrow E. and W. lake.

1336. (16th Ann. Report, p. 82.) NE ¼, NE ¼ Sec. 29, T. 65 N., R. 4 W.

"This ore is well characterized olivinitic, magnetic, granular, the yellowish waxy grains of olivine being mingled rather uniformly with the grains of magnetite."

1334, which, if the beds all dip south, is the lowermost member of this interbedded series, is mainly an aggregate of very small grains of an almost colorless augite, surrounding here and there a larger grain of the same mineral. The smaller grains are very irregular in shape, while the larger ones are long and narrow, as if vertical sections of crystals flattened parallel to their basal planes. There is a rude parallel arrangement of the grains so that the rock possesses a kind of stratified structure. In addition to the augite there are in bands in the section small grains of a greenish-brown hornblende. These are intermingled with the grains of the augite mosaic, and like these are rudely arranged in parallel directions. A few grains of magnetite scattered through the mosaic and an occasional grain of quartz complete the list of the rock's constituents. There is no evidence of any kind that the rock was ever clastic. It appears rather to be a modified eruptive. The augite mosaic has certainly resulted from the fracturing of large grains of pyroxene and the movement of the fractured parts from their original positions. In one portion of the slide this process may actually be seen in operation. A large grain of augite is granulitized around its edges, while its interior is crossed by many irregular lines of fracture, which divide the grain into hundredsof smaller ones. The slightest movement would suffice to transform this broken grain into an augite mosaic exactly like that elsewhere in the section. 1335, into which 1334 is supposed to grade, is not very different in its structure from 1334. It is an aggregate of tiny rounded grains of almost colorless augite, and grains and tiny lath-shaped crystals of plagioclase forming a mosaic in which lie much altered large grains of augite, changed on their edges to greenish-brown hornblende and peppered throughout with dust-like grains of magnetite. A few grains of the hornblende are also discovered in other parts of the slide, but they occur in such relations to the other minerals as to leave no doubt that they are derived from large grains of augite (Fig. 2). The composition, as well as

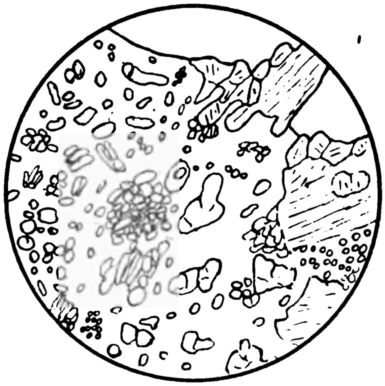

FIG. 2.

Granulitic gabbro, with large grains of green hornblende and small rounded ones of augite in a groundmass of plagioclase that appears in ordinary light to be a homogeneous mass. No. 1335,x87.

the structure of the rock, places it among the granulitic gabbros so well described by Judd,* and ascribed by him to the movement of a gabbro rock mass, while in the pasty condition just prior to complete solidification. 1336, the iron ore above 1335, is mainly an aggregate of olivine and augite, and irregular grains of magnetite. The latter mineral is in large pieces scattered between the other two, especially between the grains of olivine, and in small rounded grains included in the latter. The large pieces are apparently secondary, while the small round grains are probably original. The olivine is older than the pyroxene. It is in round grains of a yellowish green color included in large pieces of augite, and it also forms a groundmass of interlocking grains in which the plates of pyroxene lie. These latter are large and are very irregular in outline. They include olivine and stretch far out into the interstices between the grains of the groundmass. The color is bright green. There is no noticeable pleochroism and the extinction is about 35° (Fig. 3).

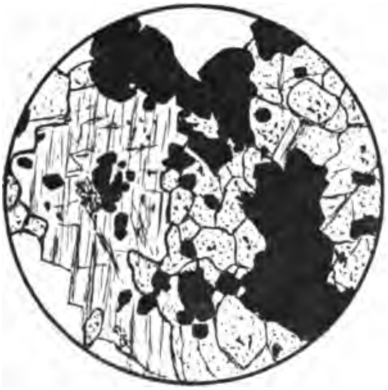

FIG. 3.
"Ore" in gabbro, consisting of olivine (stippled) hornblende (vertically striated) and magnetite (solid black). No. 1336,x27.

This rock like the others (1334 and 1335) is undoubtedly a modified eruptive. It certainly is not fragmental, nor is there any proof that it is a changed fragmental. No metamorphic rocks of this kind have ever been described, nor is it plain how such might be formed, except by complete fusion and recrystallization, in which case the result would not be distinguishable from an original eruptive. Fig. 3. shows the structure of the ore.

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* Quart. Jour. Geol. Soc., 1886, p. 49.

1340 and 1341. (16th Ann. Report, p. 85.) The quartzyte with which the ore is associated is well developed a little to the west of 1336. Here it dips 48° to the south, the quartzyte and magnetic quartz-schist being from 140 to 150 feet thick, and the associated olivinitic ore beds perhaps 50 feet. Interbedded with one of the quartzyte layers (1340) is a bed of gabbro (1341), which varies rapidly in its structure from the coarse grain of the ordinary gabbro to the fine grain of the rock called "muscovado" in the 15th, 16th, 17th and 18th Annual Reports.

1340. The so-called quartzyte, is not a fragmental rock, but is one composed of interlocking quartz-grains, including magnetite. (Fig. 4.) The latter, which is the older of the two components is often in well marked octahedrons enclosed in the quartz, but more frequently it is in rounded grains, either surrounded by a quartz individual, or situated between several of them. In the latter case the grains are slightly altered on their edges to a brownish earthy product, probably limonite, or to a green decomposition product, either chlorite or hornblende. The quartz interlocks by sutures that are perhaps not quite as irregular on the whole as the sutures of granitic quartz, but they are too irregular to be regarded as due to any cause but the crystallization of the quartz *in situ*. A comparison of fig. 4 with fig. 1 will show plainly the difference in structure between this crystallized quartzyte and the fragmental quartzitic sandstone of the Animikie.

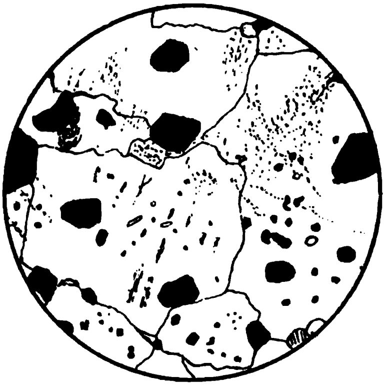

FIG. 4.

Crystallized quartzyte, associated with "ore" and granulitic gabbro. No. 1340.x27.

1341. The gabbro interbedded with the crystallized quartzyte is in an intermediate phase between the coarse grained normal olivine gabbros and the granulitic varieties, in which the pyroxene occures in small rounded grains. The olivine is in the ordinary form. The plagioclase is in irregular grains, with a tendency to the lath-shaped forms of diabasic feldspar. Its gabbroitic character is evinced in the abundance of dust-like particles scattered through it, and especially by their thick accumulation toward the centers of all grains. The pyroxene is a light-colored augite, thickly crowded with magnetite grains, small masses of limonite and tiny plates of brown biotite. Some of the augite is in ophitic plates between the feldspars, but most of it is in little rounded grains. The magnetite, nearly all of which is secondary, is thickly strewn through the section in long irregular grains in and between the other constituents, especially the augite and olivine, and in tiny rounded grains in the augite and the plagioclase.

(16th Ann. Report, pp. 86-87.) The great quartzyte of which No. 1340 is a sample, "is near the top* of the Animikie, and, since it is a new feature in the northeast part of Minnesota, it deserves a name. It apparently occupies the same horizon as the quartzyte at the head of Wauswaugoning bay. Because of the association with it of iron beds it has been called "Pewabic quartzyte."

1343 and 1346. Near the center of the NE ¼ of the SW ¼ of Sec. 25, T. 65 N., R. 5 W., the Pewabic quartzyte is again met with (1343,) dipping 55° S., and further north occurs greenstone (1345) quite like that in sections 21 and 29, T. 65 N., R. 4 W., (viz., 1334 and 1335) but approaching a little more closely to the rock called "muscovado" in other reports.

1347. (16th Ann. Report, p. 88.) The best sample of "muscovado" comes from the shore of Muscovado lake, in Sec. 36, T. 65 N., R. 5 W.

1343, which is said to be a sample of the Pewabic quartzyte, is an olivinitic rock which is probably but a very basic phase of gabbro, just as the olivine bombs of basalts are nothing† but very large accumulations of olivine and other basic minerals in the surface equivalents of the gabbros. It is composed almost exclusively of olivine and quartz. The latter is probably the younger component as it occurs in subangular grains, often entirely surrounded by olivine, to whose contours it appears to adapt itself. It includes tiny grains of magnetite, rounded ones of olivine, and some small acicular, almost colorless crystals that are thought to be pyroxene. The olivine constitutes over ninety per cent. of the entire rock. It is in closely crowded, mutually interfering, pale yellowish-green grains, containing a few magnetite inclusions and some that appear to be of glass. Occasionally an olivine grain may be included within a quartz grain, but usually the olivine forms a compact granular groundmass in the occasional interstices of which the quartz has recrystallized. Another mineral occurring in the rock in very small quantity is a bright green pyroxene that is very slightly pleochroic. The fine series of striations apparent on it indicate a diallage. This mineral is found only in very small pieces between the olivines, or between this mineral and quartz. It is probably more common in the latter position than in the former. It is undoubtedly younger than the olivine and older than the quartz. The constitution and structure of the rock point directly to the gabbros as its nearest relatives.

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*In Bulletin No. 6 of the Minnesota Geological Survey (p. 125) this quartzyte is put at the bottom of the Animikie, and it is no longer regarded as the equivalent of the Wauswaugoning quartzyte.

†Bauer: Neues Jahrb. für. Min., etc., 1891. II, p. 200.

1345 is a granulitic gabbro, composed of rounded grains of augite and plagioclase, the latter of which often include the former, and large plates of brown hornblende. The hornblende is very strongly pleochroic and is present in small flakes scattered between the augite grains, and in large ones in areas where the augite is most thickly accumulated. From the fact that many of the grains of augite in the section are partially changed to green and brown hornblende, it is inferred that all of this mineral is secondary. Its contours are very irregular and the peripheral portions of the larger plates are granulated exactly as is the augite.

1347, like 1334 and 1335, is a granulitic gabbro, but unlike the latter two rocks it contains an abundance of hypersthene and but very little olivine. All the components are beautifully fresh. The plagioclase is in very irregular pellucid grains, enclosing magnetite and hypersthene, besides a few glass inclusions. The hypersthene forms more or less rounded grains lying between the plagioclase grains, and sometimes included in them. It is pleochroic in deep pink and light green tints, and it includes a few magnetite grains. In many portions of the section the grains are isolated, but in other portions they unite to form accumulations, between the grains of which large masses of magnetite lie. The olivine, when present, is in large irregular grains, very much decomposed with the production of much magnetite.

The relation of this rock to a gabbro is too clear to need emphasizing. The components are those of the gabbros, while the structure corresponds exactly to that of the granulitized varieties.

### DISCUSSION.

Of the rocks above described, 1327 is a fragmental quartzyte, 1329 a diabase, 1334, 1335, 1345 and 1347 are granulitic gabbros, 1341 is an intermediate phase between the normal gabbros and the granulitic varieties, 1336 a very basic aggregate of gabbro components, 1343 a similar basic aggregate with the addition of quartz, and 1340 a crystallized quartzyte.

In the 16th Annual Report of the Minnesota Geological Survey, 1327 is called a chert, 1336 an Animikie bed (presumably quartzyte) carrying ore, 1340 a quartzyte (presumably fragmental), 1343 quartzyte (Pewabic quartzyte), and 1345 and 1347 "muscovado."

The most evident results of the microscopic study of the rocks are with respect to their nature. 1327 is not a chert, but like all the other non-eruptive Animikie beds described, it is a sedimentary clastic rock.

The "muscovados" that have so frequently been mentioned in the reports as very peculiar basic rocks whose true nature is unknown, have been learned to be granulitic phases (sometimes quartzitic) of the very common gabbros so prevalent in northeastern Minnesota.

The "Pewabic quartzyte" (1343) and its associated ores (1336) are about as far removed from being quartzytes as possible. Instead of being acid fragmental rocks, most of them are basic crystalline ones, and from their very nature they may safely be considered as phases of gabbro.*

From the single section of 1340 it is not possible to learn much. However, the rock is not a fragmental quartzyte like the quartzyte of the Animikie beds, and consequently cannot be regarded as the equivalent of fragmental quartzytes existing at other places in the lake Superior basin. If we may be permitted to interpret the result of the study of section 1340 by means of the knowledge gained during the investigation of a suite of specimens collected from the Akeley lake region by the United States Geological Survey, we must conclude that this rock, though a completely crystallized quartzyte, is nothing more nor less than an extreme phase of the gabbro. In other words, it is a completely altered gabbro rather than an independent rock species, and hence it must be classed with the gabbro overlying the Animikie and not with the Animikie fragmentals.

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* In this paragraph it is not intended to deny the possibility of any of the so-called Pewabic quartzytes being true fragmentals. It is merely asserted that much of this rock in the Akeley lake region is a phase of gabbro, and that none of it in this neighborhood is fragmental.

From the above statements it is quite clear that some of the conclusions reached by the Minnesota geologists with respect to the relations of the Akeley lake ores to the Animike beds must be modified. From the mere fact that the former dip south at high angles (30°-55°), while all of the Animike beds are only moderately inclined (12°-25°), it might be argued that the two series are different. A stronger argument, however, is discovered when we learn that none of the beds belonging to the former series are fragmental, while all of those of the Animike are either clastic or but slightly altered diabases. Moreover the Akeley lake ores are underlain by modified gabbro, while the ores themselves are probably phases of the same rock, which extends from this place southward for many miles as a typical olivine-gabbro. We must then class the ores, and even much of the rock called "Pewabic quartzyte" with the gabbros. Even though some of the rock called "Pewabic quartzyte" may be a true quartzyte in the Animikie, it is evident that it is not of as great importance for correlation purposes as has been supposed.

Some of the conclusions published in the 16th report (pp. 84, 85) of the Minnesota Survey, must thus be modified before they can be accepted as correct. Without entering further into the discussion of the various conclusions in detail, it will prove sufficient for the present purpose to state them briefly in their modified forms. The changes, which the writer thinks are necessitated by the knowledge of the true nature of the rocks concerned, may be learned by comparison of the original conclusions* as published in the Minnesota report, with those here given.

1. The ore beds of the Akeley lake series belong with the overlying gabbro, and not with the Animikie.
2. The iron-bearing rock is a phase of the gabbro into which it passes above.

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* The numbering of the conclusions corresponds with that used in the Minnesota report.

3. The bedded rocks of the iron belt are granulitic gabbros, and consequently are eruptives, and not changed sedimentaries.

4 and 5 may stand unchanged, if by quartzyte is not understood a fragmental rock.

6. The rocks interbedded with the ores are special phases of gabbro.

7, 8 and 9 remain unchanged so far as the conclusions are concerned.

10. Since the so-called Pewabic quartzyte of the Akeley lake region is in most cases a gabbro, it cannot be correlated with quartzytes in the Animikie in other regions. In the Akeley lake region it is certainly near the bottom of the gabbro.

## (II) OCCURRENCE AND DESCRIPTION OF SPECIMENS MENTIONED IN THE 17TH REPORT.

451 (H) and 452 (H). (17th Ann. Report, p. 107.) NW¼ Sec. 28, T. 65 N., R. 4 W.

Southeast of 1334 and 1335, and east of 1336, 1340 and 1341, and nearly on their strike, are beds of Animikie (?) slate and ore, dipping at 60°–75°, and lying upon a biotitic gabbro, which has slightly metamorphosed their lowest quartzitic and ore layers. Nos. 451 and 452 show the changes and gradation of the Animikie beds as they become crystalline and pass through metamorphosed strata into the greenstone.

453 (H). (17th Ann. Report, p. 108,) is another specimen of the Animikie from a drill hole a little to the south of 451 and 452.

451 (H), like the rocks to the west of it, is a gabbro, and not a fragmental rock in any sense of the word. Its structure, like that of 1341, is intermediate between that of the true gabbros and that of the granulitic varieties. It contains large plates of almost colorless augite and of strongly pleochroic hypersthene, surrounded by an aggregate of rounded grains of the same minerals, flakes of brown biotite and irregular grains of colorless plagioclase. In the immediate neighborhood of the larger pyroxenes the small grains of this mineral are orientated to correspond with the orientation of the larger ones, from which they are separated by the plagioclase. The biotite is in large flakes with strong pleochroism in bright yellow and

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size, and since the latter are undoubtedly secondary, it is inferred that the larger ones are also secondary, and that their great abundance in the neighborhood of the plagioclase is due to a reaction between this mineral and the augite.

There are other interesting features connected with this slide, but enough has been said to indicate that the rock from which it was made is a true gabbro, in which the beginning of a granulitization of the pyroxene may be detected.

456B (H) differs from 456C (H), mainly in that the plagioclase is more frequently in lath-shaped individuals, and the pyroxene is more completely granulated. Magnetite and biotite are less abundant than in 456C (H), and hypersthene may be more abundant. The rock approaches more nearly the granulitic gabbros than the normal phases of this rock.

456A (H) is a very fine-grained granulitic rock, containing a very large quantity of biotite and magnetite. Occasionally the feldspars have long, narrow cross sections, but in this respect only does the rock resemble diabase. Most of the plagioclase as well as all of the pyroxene is in rounded grains. The magnetite is in irregular grains and in little crystals, and the biotite is in small flakes that are about as broad as they are long. The features are those of a fine-grained eruptive with gabbro characteristics.

456 (H), which, according to the descriptions in the 17th Report, is a specimen taken from the immediate contact of the gabbro with the overlying beds, is a granulitic gabbro, in which is a vein of very coarse pyroxene. The granulitic portion of the rock is not very different from 456B (H). It is an aggregate of small grains of pyroxene, and of pellucid plagioclase, together with small plates of brown biotite, all including many smaller grains of magnetite, and all arranged in a somewhat parallel manner, that is not the result of pressure. Through this passes a vein of irregularly interlocking, coarse grains of pyroxene, both augite and diallage, and greenish-brown hornblende, scattered through which are a few plates of biotite and grains of plagioclase and magnetite. Along the edges of the vein the amounts of green hornblende, of biotite, and of magnetite increase, and the structure gradually becomes granulitic.

These four specimens are thus seen to belong with the gabbro. The granulitic variety can be traced back into a rock that shows but traces of granulitization, so that there can be but little doubt that the former are, as has been repeatedly stated, but special phases of the latter. The greenstones underlying the supposed Animikie rocks in this place are then not Keewatin, but they are identical in every respect with the overlying rock, which is certainly not Keewatin.

455A (H). The section of this rock, which is a sample of the supposed Animikie above the greenstone, consists of two very distinct portions. The major part is composed of thickly crowded plates of hypersthene, filled with magnetite and including an occasional grain of quartz. The minor portion is like the crystallized quartzytes 452 (H) and 454 (H), though the quartz grains are perhaps a little more rounded than in these two cases. They include magnetite and rounded grains of hypersthene and numerous large liquid cavities, and are often separated from each other by thin seams of limonite. Between the two areas mentioned is a sort of transition zone in which the quartz-grains and hypersthene are intermingled in about equal proportions with the latter between the grains of the former.

The quartzitic portion of this rock is either a vein in it, or it is but a very acid phase of the granulitic gabbro. In the hand specimen the quartzitic band is but a fraction of an inch in width. In either case the rock loses its importance as a means for determining the age of the gabbro. It is certainly not part of a clastic bed, but it is a portion of the gabbro.

458 (H). (17th Ann. Report, p. 110.) North of the bluff from which 456 (H), etc., were taken, is a still higher ridge in which the rock appears to be slightly different from that in the southern ridge. This rock, under the microscope, is found to be a very fine-grained granulitic aggregate of colorless augite and plagioclase, with a little mica and magnetite and large decomposed areas of what were perhaps originally idiomorphic grains of augite. At present these larger areas consist largely of magnetite dust and green hornblende.

## DISCUSSION.

It will not be necessary to discuss the bearing of the nature of the rocks described in the 17th Report upon the geology of the Akeley lake region at as great length as was done in the case of those mentioned in the 16th Report. It will be sufficient to call attention to the fact that the investigation of the former rocks substantiates the conclusions deduced from the study of those whose locations are given in the latter report.

All the beds that were supposed to be Animikie are discovered to be quite unlike any beds that are known to belong to this formation. They all dip at higher angles than do the Animikie rocks, and at the same angle as do some beds that are undoubtedly a part of the great gabbro flow. Moreover, most of the supposed Animikie layers are not fragmental. They are granulitic gabbros that may be traced step by step into a true gabbro, which has all the characteristics of the great gabbro of Minnesota, and which is entirely different from the thin beds of so-called gabbro that are interleaved with the Animikie. The quartzytes among these layers are not fragmental quartzytes, and hence can not be correlated with true fragmental quartzytes as far removed from them as those of Pokegama falls or the falls of Prairie river.* The writer would place them and their contained ores with the gabbro group† of Prof. Winchell. Even should the quartz layers interstratified with the granulitic gabbros be regarded as recrystallized fragmental beds, they would not have the same important significance as would be the case were they truly interstratified fragmentals, for they would owe their present condition to the action upon them of a later eruptive—the gabbro—and thus they could not be used to determine the age of this latter.

## SUMMARY.

The three important results reached largely by the microscopic study of the rocks from the neighborhood of Akeley lake, are these:

1. Most of the rocks designated as Pewabic quartzyte in the neighborhood of Akeley lake are not quartzytes, but they are granulitic phases of gabbro. The remainder are crystallized aggregates of quartz. None of them are sedimentary rocks, and consequently none can serve to determine the age of the ore associated with them, or of the gabbro in which they occur.

2. On the other hand, the granulitic gabbros may be traced into true granitic gabbros, and into quartzose phases of granulitic varieties. Hence, the granulitic beds and their associated ores, are of the same age as the gabbro, whose structural relations to the younger and older formations must be appealed to in order to settle the question of age.

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* Cf. The Iron Ores of Minnesota: Bull. 6, Minn. Geol. Survey, p. 119.

† Iron Ores of Minnesota, p. 123.

3. Since so much of the "Pewabic quartzyte" is not quartzyte in any sense of the word, and since different beds that have been given this name are not all certainly of the same age*, it is evident that great care must be taken in the use of the "Pewabic quartzyte" for correlation purposes. Several different rocks have been included under this one title, hence, the "Pewabic quartzyte," as defined, cannot be relied upon as marking a definite horizon in the succession of the geological formations in northeastern Minnesota.†

## APPENDIX.

Since the above was written, the attention of the writer has been called to the fact that the first and second of the above conclusions are practically identical with those reached by the Lake Superior Division of the United States Geological Survey several years ago. In 1883 and 1884 Mr. W. M. Chauvenet examined in the field the Akeley lake district and that to the westward. Thin sections of his material were examined by Prof. C. R. Van Hise early in 1885. With his field notes as a basis, and the microscopical results of Prof. Van Hise, he submitted a report to Prof. Irving from which the following abstracts are condensed:

Near Little Saganaga lake "An outcrop of heavy magnetitic iron ore rises in a smooth shoulder between walls of a distinctly bedded rock having the appearance of a quartzyte, but which proves under the microscope to be an olivine gabbro with quartz replacement. * * * The silicified gabbro shows distinct banding, stained with iron oxide along the contact of the layers. * * * The bed of magnetic ore occurs, therefore, in the gabbro formation."

The Akeley lake section is fully described. "Along the ridge on the north shore of Akeley lake a number of trenches were opened, which exposed a magnetic ore here occurring in the gabbro. The occurrence is quite similar to that described at Little Saganaga."

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*Some are Animikie as determined by Prof. Winchell, while others are of the same age as the gabbro, which is regarded by the Minnesota geologists as Animikie, only because of the supposed interstratification with it of the granulitic gabbros. which were thought to be Animikie quartzyte.

†It is possible that by including under the Pewabic quartzyte only such rocks as are undoubtedly fragmental, as the quartzyte east of Gunflint lake and those along the south side of the Mesabi Range, a constant horizon may be established, which will be of great service in determining the ages of overlying and underlying beds. These rocks, however, cannot be correlated with the granulitic gabbros of the Akeley lake region nor their ores with the ores in the latter. It is this point upon which emphasis is especially placed in the above article.

Then follow details of the alternations of ordinary gabbro and what appears to be bedded quartzyte, after which it is said:

"The quartzytes of the above layers all appear to be merely the result of a substitution of quartz and magnetite for the minerals of a gabbro, in some cases for an olivine gabbro. * * * The silicified gabbro on Akeley lake, with seams of magnetite, have been traced southwest through Sections 25, 35, 34, T. 65 N., R. 5 W., to Mitchigamme lake."

Finally the following conclusion is drawn: "It is evident, from a study of the rocks at Akeley lake that the iron ore here lies wholly in the gabbro formation, much silicified and altered, and not in the Animikie."

Mr. W. N. Merriam, in 1886, made farther observations on the silicified gabbro belt at lake Gobbemichigomog and vicinity. The sections obtained from the material collected by Mr. Merriam were examined by Prof. Van Hise with the same results as those reached in the case of the Akeley lake rocks.

It thus appears that the Akeley lake silicified gabbro has a considerable east and west extent along the north contact of the gabbro, and that the results which have been reached from a study of the specimens collected by the Minnesota Survey are in accordance with those made by others in an independent study of which the writer was wholly ignorant until his paper was entirely written.

*Colby University, Jan. 11, 1892.*

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NOTE.—The second foot note on the bottom of p. 209, expressing the main point of difference between the conclusions of Prof. Bailey and the reports of the Minnesota survey, is the only one to which here it is appropriate to call attention to. The minor variations in lithologic distinctions, when not due to insufficiency of the supply of material in Prof. Bailey's hands, can all be accounted for and are of but little purport in considering the general succession and structural relations of the formations. It is probable that when Prof. Bailey has seen the structural facts in the field he will modify his conclusions respecting the continuity of the Pewabic quartzyte from the Akeley lake region toward the southwest, and even to Pokegama falls.

There is, as the Minnesota reports have fully explained, a wonderful variety of lithology in the lower part of the Animikie by the agency of cotemporary eruptive action. The "non-fragmental" silica is a chemical precipitate in the early Animikie ocean. At distant points it is pure silica, in rolled grains. At points near the eruptive centers, as at Akeley lake, it has not only not acquired the rounded "fragmental conditions" but it has been crystrllized *in situ* by the heated eruptives, and has been mingled with tufaceous, eruptive fragmental elements. When this mixture is recrystallized it has a remote resemblance to an eruptive rock. But it is of oceanic structure, outwardly and internally, and cannot be affiliated correctly with the true eruptive gabbro.

Of course the intent of Prof. Bailey's paper is to establish the idea of Prof. Irving that the gabbro flood is later than the Animikie rather than near the bottom of it where the Minnesota geologists have placed it, but its purport confirms the Minnesota geologists in their conclusions. N. H. W.

# NEW LOWER SILURIAN LAMELLIBRANCHIATA, CHIEFLY FROM MINNESOTA ROCKS.

BY E. O. ULRICH.

In the following pages I endeavor to give full descriptions and, it is hoped, sufficient illustrations of the principal and generally the more striking of the new Minnesota forms of this class that have been brought to my notice since 1885. Much of the material now described I owe to the disinterested kindness of Prof. C. W. Hall, of the State University, and to the unfailing friendship of my co-laborer, Mr. W. H. Scofield, of Cannon Falls. The last sent me every shell and cast of the interior contained in his extensive private cabinet. Many were in a good state of preservation, several belonged to species that I had not before seen (among them the remarkable shell from which I was enabled to work out the characters of the new genus *Plethocardia*), and all proved of material aid to me in determining the essential characters, variations, and limits of the species studied. The value of such aid may be better appreciated when I state that the Minnesota Trenton Lamellibranchiata are no exception to a rule that seems to prevail nearly every where in these rocks, namely, that in most cases the individuals of the species are anything but abundant. Yet, a few forms have been found in considerable numbers, and my observation would indicate that the majority of these shells are more or less gregarious in their habits, so that the number of known specimens of a species may at any time be greatly augmented.

In the Minnesota Lower Silurian rocks, excluding the beds beneath the top of the St. Peter's sandstone, the Lamellibranchiata are confined very largely to six horizons. The first of these is in the upper part of the Trenton limestone in which the fossil itself is almost invariably dissolved away so as to leave good moulds of both the exterior and interior in the matrix. This method of preservation is most favorable, since with the aid of gutta percha the judicious collector may study the most important of the original characters of the shells with comparative ease. Individuals of *Cypricardites rotundus* Hall, are abundant, while another form of the genus near *C. ventricosus* Hall, and *Modiolopsis plana*, of the same author, are not uncommon. The types of *Cypricardites sardesoni* and *C. obtusifrons*, of this paper, are from the same bed, as are several other forms not yet specifically determined.

The second horizon is in the middle third or "Rhinidictya beds" of the Trenton shales. It has afforded *Modiolopsis similis*, *Orthodesma minnesotense*, *Technophorus extenuatus*, *Tellinomya nitida*, *Cypricardites cingulatus*, *C. glabellus*, *C. obtusifrons?*, *Whitella compressa*, and *W. concentrica*, all described by the author. Several other species are represented in my collections by specimens too illy preserved to admit of a satisfactory determination of their affinities.

The third horizon is in a bed that I place near the top of the upper third of the Trenton shales. It is exposed at a locality about six miles south of Cannon Falls, Minn., where it is overlaid by the Galena shales. It is the most interesting horizon for these fossils known to me in the state. Perhaps it is a local deposit, at any rate, none of the Lamellibranchiata described by me from this locality are as yet known in the same position from other points. An incomplete list of the species is as follows: *Tellinomya compressa*, *T. levata* (Hall), *T. planodorsata*, *T. pulchella* (Hall), *Lyrodesma poststriatum* (Emmons), *Modiolopsis concava*, *M. faba?* (Emmons), *Matheria rugosa*, *Cypricardites tenellus*, *C. haynianus?* (Safford), *Whitella scofieldi*, and *Plethocardia umbonata*. All of these species are preserved with the shell, from which the matrix can be cleaned with unusual ease.

In the fourth horizon, a bed of light colored shales underlying the Galena limestone, known to the survey as the Galena shales, all the shells of this class are preserved as casts of the interior. These are sometimes highly satisfactory, yet too often the opposite is true. Many of the specimens from this horizon therefore remain unclassified, and until better material becomes available it will not be possible to give a full list of the species. At least two, and very likely three species of *Cypricardites*, one of them probably *C. haynianus* (Safford), can be made out, besides *Tellinomya levata* (Hall), *T. planodorsata*, *Modiolopsis subelliptica*, *Whitella truncata*, and *Plethocardia suberecta*. There is also an elongate *Tellinomya* near *T. nasuta* Hall, a *Modiolopsis* near *mytiloides* Hall, and enough of other distinguishable forms to bring the total number to fifteen or more.

The fifth horizon is a layer a few feet thick at the base of the Galena limestone that I have named the "Platystrophia beds" in an unpublished section of the Lower Silurian rocks of Minnesota. From this bed I have seen *Cypricardites tenellus*, *C. nanus?*, *Tellinomya astartiformis* (Salter), *T. intermedia*, *Cleidophorus consuetus*, and several undetermined forms.

The sixth horizon occurs in the Hudson river group at Spring Valley and other points in the southern part of the state. This formation is very thin in Minnesota, and the part represented is equivalent to the upper beds of the group as developed in Ohio and Indiana. Fossils are exceedingly plentiful in some of the layers, but consist chiefly of Brachiopoda. As a rule the Lamellibranchiata have suffered through compression, but a good proportion are in an excellent state of preservation. Among them I have recognized *Ambonychia casei* Meek and Worthen, *Whitella obliqua*, *Lyrodesma major* (described originally by me as *Cleidophorus major*), *Tellinomya recurva*, and *T. similis*, all species occurring also in Ohio. The *Cuneamya sulcodorsata* is, so far as is now known, restricted to this locality. Among the undetermined forms there is a *Modiolopsis* near *pholadiformis* (Hall), another near *M. concentrica* (Hall and Whitfield), one or two species of *Orthodesma*, and a *Tellinomya* near *iphigenia* of Billings.

Respecting the classification of Silurian Lamellibranchiata, it may be well to state that with the progress of our studies we have now arrived at a point where we can appreciate the heterogeneous character of the numerous forms grouped under the generic names *Modiolopsis*, and *Cypricardites*, and in a less degree *Pterinea*, *Ambonychia*, *Tellinomya*, *Cleidophorus*, and *Orthodesma*. I realize fully the inadequacy of the present grouping of the species, yet follow in the same tracks because I fail to see any remedy giving both rapid and permanent relief. Now and then a sharply distinguishable, because essentially Silurian, generic type may be encountered, but many others are indicated which it would be unwise to separate before being closely compared with the wealth of Devonian and Carboniferous forms now known. But that involved more time and labor than I found myself able to devote to the subject, and rather than increase the difficulties of revision, which must be undertaken sooner or later, I have, perhaps unwisely, allowed many species that were determined over ten years ago to be new to science, to lie unpublished in my cabinet. After fully considering the matter, it now appears to me that an incomplete knowledge of our fossil Lamellibranchiata is better than none at all, since the necessity for work in the branch will become all the more evident to students. It was therefore largely in the hope of enticing other energies to the field that I began a series of publications on the subject in the American Geologist. The first of these appeared in the May number, the second in the September, and the third in the December number of that journal, during 1890. It was my intention to continue the papers through the two volumes for 1891, but illness prevented. Among the contemplated papers, one or more which I hope to publish during the present year, is one on species of *Tellinomya* and *Lyrodesma*, a second on *Cleidophorus*, *Cycloconcha*, and *Matheria*, a third on *Orthodesma* and related genera, a fourth on *Cuneamya*, and a fifth on *Ambonychia* and *Pterinea*. When these are published, and the results added to the present paper and the previous publications by Hall, Miller, Meek, and others, the Lower Silurian Lamellibranchiata will have arrived at a promising stage for good classificatory or monographical treatment. Whether or not I shall extend my work on them beyond that stage depends upon circumstances and the success of my endeavors to induce some one of our young paleontologists to take up the group as his specialty.

Two disputed points of nomenclature came up during the preparation of the present paper. The first pertains to the claims for recognition of *Ctenodonta*, Salter, as opposed to *Tellinomya*, of Hall. The latter name has priority, but Hall's original description is so faulty that no blame can attach to Salter for failing to recognize the genus. *Ctenodonta*, on the other hand, was established in a manner so satisfactory that no marked improvement on his diagnosis has since been attempted. Salter's name was adopted by Billings and Safford in this country, and it is now quite generally used in Europe. Hall's name however is used by most American authors. My own views on the points at issue are undecided, and I wish it to be understood that the adoption of *Tellinomya* in the following pages is not to be considered as final, but rather as provisional and in deference to the views of friends and the claims of the venerable author of the name.

The second point, relating to *Cypricardites* of Conrad and *Cyrtodonta* of Billings, brings up questions equally difficult to decide. I shall not here enter upon a discussion of the claims so ably upheld by Hall on the one side, and Billings on the other, and my adoption of *Cypricardites* is to be considered as no more final than in the case of *Tellinomya versus Ctenodonta*.

The thirty two cuts which illustrate the species described in this paper have been reproduced from my own drawings. In every case the figures have been drawn with great care, and may be relied upon as representing the characters of the species so far as they are known to me.

In describing the rostral portion of the shells it will be noticed that I have, contrary to common usage, often drawn a slight distinction between the terms *beaks* and *umbones*. To meet the want of some term to indicate that portion of the beak which is visible in a side view, I call it the *umbone*, while the application of the term *beak* was restricted to the incurved extremity that in most cases is visible only in a dorsal or anterior view.

## TELLINOMYA NITIDA, n. sp.

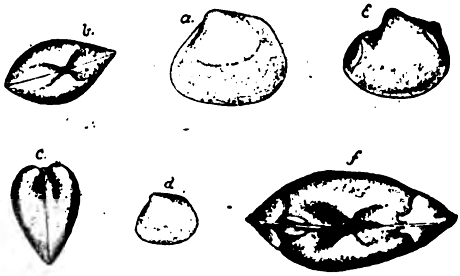


FIG. 1. *Tellinomya nitida*, n. sp. *a*, *b* and *c*, left side, cardinal, and posterior views x2, of a small specimen retaining the shell; *d*, natural size view of same; *e*, left side of a large and very perfect cast of the interior, nat. size; *f*, cardinal view of same, x2 to show the muscular scars.

Shell small, thin, moderately ventricose, subtriangular, the antero-cardinal region somewhat alated; umbones full, beaks closely incurved. Posterior extremity oblique, rather abruptly truncated, flattened, nearly straight, pinched and projecting slightly beyond the convex part of the shell in the upper half, and narrowly rounded below. Ventral margin gently convex, usually curving rather sharply upward at the ends. Anterior end wide, rounded and most prominent in the lower half, straightened above, the junction with the hinge-line subangular. Surface, excepting a few indistinct lines of growth, smooth.

Casts of the interior have strongly projecting beaks. The internal characters of the shell, so far as they can be made out from these casts, are as follows: Hinge line very slightly arcuate, with eight or nine strong teeth behind the beaks, and an undetermined nu [illegible] smaller ones in front. Anterior and posterior muscular impressions subequal, distinct, the posterior ones drawn out along the hinge margins. Above the anterior pair there is another much smaller elongated pair, lying close to the hinge. These features are all shown in fig. *f* of the above cut.

This species evidently belongs to the group of species of which *T. levata* Hall is a type, but its posterior end is shorter and more abruptly truncated, agreeing in that respect more closely with *T. abrupta* (*Ctenodonta abrupta* Billings). The latter however is a more ventricose and longer shell, and not as wide anteriorly.

*Formation and locality*:—Good specimens of this species with the shell are exceedingly rare, but casts of the interior are common in the middle third of the Trenton shales, of Minneapolis, Fountain and other localities in the state of Minnesota.

## TELLINOMYA COMPRESSA, n. sp.

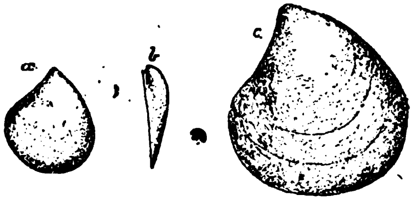


FIG. 2. *Tellinomya compressa*, n. sp. *a*, right valve of this species; *b*, posterior view of same; *c*, same, x2, showing the extremely fine concentric lines of the surface. These are preserved at the posterior end of the shell only.

Shell small, erect, the height greater than the length, subtriangular, compressed, thin; beaks small, almost acuminate, moderately incurved; umbones rather flat, the convex part of the shell terminating somewhat abruptly along the anterior and posterior cardinal margins. In the outline, these two margins, meeting at the beaks, form an angle of about 85 degrees, with the anterior gently convex and the posterior correspondingly concave. Aside from this difference in the curvature of the upper parts the ends are subequal, and round uniformly into the strongly convex ventral edge. Surface with faint lines of growth, and exceedingly fine, crowded, concentric striæ, six to eight in one mm.

Hinge line bent at a right angle, with about twenty teeth, the central ones very small, those on each side larger and bent. Muscular impressions not observed.

This species forms one extreme and *T. pectunculoides* Hall, the other, of a group of at least ten species of which *T. astartiformis* Salter, may be taken as the type. They are all much shorter than the species of the typical section of the genus.

Compared with related species *T. alta* Hall, is more erect, more ventricose, with the ventral margin less convex, and a thicker shell. *T. astartiformis* is near but differs in being more ventricose, more coarsely striated, and in having more obtuse beaks. Salter's species, excepting that it is more ventricose than either, is in all other respects very nearly intermediate between *T. compressa* and *T. intermedia.*

*Formation and locality:*—In the upper third of the Trenton shales, six miles south of Cannon Falls, Minnesota. It is here associated with *T. levata?* Hall, *T. pulchella* Hall, *Lyrodesma postriatum* Emmons, *Modiolopsis concava*, n. sp. and a fossil very much like *Salterella billingsi* Safford.

## TELLINOMYA PLANODORSATA, n. sp.

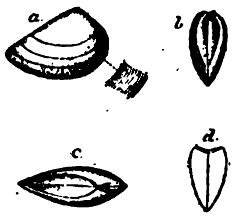


FIG. 3. *Tellinomya planodorsata*, n. sp., *a*, *b*, and *c*, left side, posterior, and dorsal views of the nearly perfect type specimen of this species, nat. size; *d*. sectional view of same, with the posterior dorsal side at the top of the figure.

Shell small, depressed convex, subtriangular or trapezoidal, the width and length respectively as ten is to fourteen; beaks small, incurved, scarcely projecting above the hinge, and situated about one third of the entire length from the anterior extremity. Posterior end long, subtriangular in outline, with the extremity subacute, and the dorsal side almost straight (faintly convex) from the beaks backward; ventral margin broadly rounded, anterior edge more strongly convex. Postero-cardinal side thick, with a large, sharply defined, and slightly concave lunette, reaching from the beaks to near the posterior extremity of the shell. Surface gently convex, scarcely sloping toward the lunette, marked with exceedingly fine striæ and a few stronger lines of growth.

Interior unknown, unless a cast of the interior from the overlying Galena shales belongs to this species. This cast which was formed by a shell of scarcely three fifths the length of the type specimen, agrees in most respects, only the beaks project considerably above the hinge line, causing the posterior cardinal line to be concave instead of straight or slightly convex. Still, we must remember that it is the inner or lower side of the hinge plate that is represented in the internal cast, and as this is always thicker in these shells than the shell substance at the head of the beaks, it is to be expected that the latter would be more prominent in the casts than in the shell itself. The cast in question is considerably like those of *T. levata* Hall, differing mainly in being a little longer, less ventricose, with the back flatter, and in having the muscular scars much less distinct. Indeed, the latter are so faint that their shapes cannot be made out with certainty—a condition, again, to be expected in a species that evidently depended chiefly upon the large size and strength of the external ligament to keep its valves in position.

Taking the shell itself, I know of no species with which it might be confounded.

*Formation and locality:*—Same as the preceding.

## TELLINOMYA INTERMEDIA, n. sp.

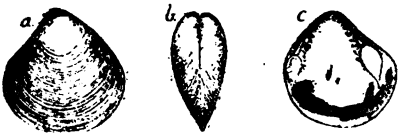


FIG. 4. *Tellinomya intermedia*, n. sp. *a*, and *b*, right and posterior views of an average example of this species, nat. size; *c*, cast of the interior of a left valve, nat. size, showing muscular scars, impressions of hinge teeth, and obtusely ridged character of the antero-cardinal region.

Shell thin, of medium size, moderately ventricose, rather erect, the height a little greater than the length. Outline subtriangular, at the beaks, which are obtusely acuminate and incurved, forming very nearly a right angle; anterior cardinal margin very gently convex, posterior cardinal edge correspondingly concave, ventral margin together with the curve into the ends forming a semicircle. Ends sub-equal, the posterior sometimes a little the longest (see fig. 4 *c*.). Umbones full, the remainder of the surface sloping uniformly to the free margins. An obscure sulcus may be detected near the anterior margin, and along the dorsal part of this end the surface descends abruptly to the hinge plane. Surface with strong, closely arranged, thread-like, concentric lines, about twelve in 5 mm. At intervals of about two or three mm. generally a fold stronger than the rest.

Casts of the interior exhibit a faint ridge and sulcus in the anterior end, two sharply defined muscular scars and pallial line in each valve, and above the posterior pair a much smaller pair of scars situated close to the hinge. Hinge plate rather narrow, the teeth numerous, over thirty, as usual very small centrally, growing larger gradually toward the ends of the hinge.

This species is associated with and closely related to *T. astartiformis*, described by Salter from the Black River and Trenton limestones of Canada, but is a less ventricose shell, with coarser striæ, and more rounded ends and ventral margin. *T. compressa*, occupying a lower horizon, is more compressed, higher, has sharper beaks, and much finer striæ. Both *T. subrotunda* and *T.* (?) *hamburgensis* Walcott (Mon. U. S. Geol. Sur., vol. 8, p. 76) have a more rounded outline.

A very similar but smaller and clearly distinct species, differing chiefly in the crenulation of the hinge, occurs in the Utica horizon of the Cincinnati group, at Covington, Kentucky.

*Formation and locality*:—Not uncommon at the Platystrophia horizon at the base of the Galena limestones, near Fountain, Minnesota.

## TELLINOMYA SUBROTUNDA, n. sp.

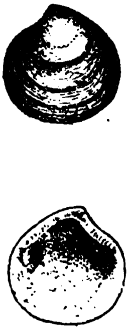


FIG. 5. *Tellinomya subrotunda*, n. sp. Two views, external and internal, of a well preserved right valve, nat. size.

Shell of medium size, comparatively thick, compressed, nearly circular in outline, with the beaks small, prominent, rather acuminate, curving inward and posteriorly. Posterior dorsal line straight except just beneath the beaks where it is concave. Anterior dorsal margin gently convex, rounding gradually into the general outline. Umbones small, the surface almost uniformly depressed-convex. At intervals of from two to three mm., the surface presents strong, lamellose lines of growth, and between these much finer concentric lines, about six in two mm.

Interior with subequal, ovate, moderately impressed, anterior and posterior muscular scars. Hinge plate strong, bent at a little more than a right angle, with numerous (about thirty-five) small teeth, as usual strongest near the extremities of the hinge.

This species is more rounded and less ventricose than *T. intermedia*, is more rounded and evenly convex than *T. compressa*, and has more prominent beaks and more abruptly bent hinge than *T. pectunculoides* Hall. A species intermediate in character between the last and the present form, and the nearest relative of *T. subrotunda* known to me, occurs in the upper beds of the Cincinnati group at several localities in Ohio.

*Formation and locality*:—Base of the Trenton limestones, Mercer county, Kentucky. It is possible that certain illy preserved casts of the interior, from the upper part of the Trenton shales, near Cannon Falls, Minnesota, may belong to this species.

## TELLINOMYA SIMILIS, n. sp.

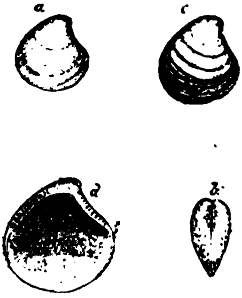


FIG. 6. *Tellinomya similis*, n. sp. *a* and *b*, left and posterior views of a rather small shell; *c*, left side of another specimen; *d*, interior of a large right valve. All the figures are of the natural size.

Shell small to medium size, moderately ventricose, subtriangular, the length and height respectively as five is to six. Umbones full, rounded, the rostral portion strongly recurved, with the beaks small, and projecting slightly above the hinge. Antero-dorsal edge convex, thick, flattened, but not sharply defined. Postero-dorsal edge rather strongly concave, impressed so as to form an illy defined, imperfect lunette. Anterior side almost uniformly convex, curving neatly into the well rounded ventral margin. Posterior side rather narrowly rounded and slightly produced in the lower half. Surface almost uniformly convex, highest a little above the center, generally with a few well-marked varices of growth, and with finer concentric lines in the lower part. Hinge plate of moderate strength, with numerous small teeth (thirty-five to forty-two), in the largest example seen with about twenty-seven anterior and fifteen posterior to the beak. Posterior teeth the largest, bent. Muscular scars faintly impressed.

The shape of this species is exceedingly like that of *T. astartiformis* Salter, of the Black River and Trenton limestones, but it is not so ventricose. If the hinge of that species is correctly represented in Salter's figures, the form under consideration must be regarded as specifically distinct, since it has smaller, less bent and more numerous teeth. According to Salter the teeth of *T. astartiformis* are largest on the anterior side, while in *T. similis* the opposite is the case.

It is also very much like its associate, *T. recurva*, but is distinguished by being a little higher, more uniformly rounded on the anterior side, and without the anterior sulcus. More important differences are the greater tumidity of the umbones, less prominent beaks, scarcely defined posterior lunette, and less strong hinge plate. Casts of the interior are separated chiefly by the greater thickness of the rostral portion. They are also nearly always of smaller size than those of *T. recurva*.

*Formation and locality*:—Upper beds of the Hudson River group, Spring Valley, Minnesota, and Blanchester, Ohio.

## TELLINOMYA RECURVA, n. sp.

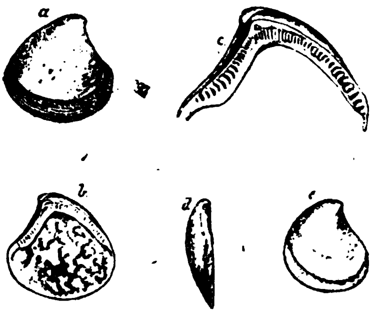


Fig. 7, *Tellinomya recurva*, n. sp. *a* and *b*, external and internal views of a left valve, nat. size; *c*, hinge of same, x2; *d*, posterior view of same; *e*, another left valve, nat. size, of somewhat different shape. Specimens from Spring Valley, Minn.

Shell small or of medium size, not thick, rather compressed, subtriangular, the length and height almost equal. Rostral portion strongly recurved, umbones small, depressed, beaks very prominent, posterior to the center of the shell. Dorsal slopes flattened, sharply defined, with the ridges projecting beyond or overhanging the edge of the hinge plate. This is true especially of the posterior side, where they form an elongated lunette. Anterior dorsal margin more strongly convex than in any other species known; posterior dorsal margin correspondingly concave. Outline, with the anterior side rather sharply rounded in the lower half, the ventral margin sloping backward and most prominent a little behind the center, then curving upward to meet the concave posterior side at a point very nearly opposite the middle of the height of the shell. Posterior end rather narrowly rounded, most prominent just beneath the center. Surface with several strong growth lines, and between them fine concentric striæ, about ten in three mm. An obscure sulcus extends from the beak along the anterior margin to the antero-ventral region. Hinge plate very strong, bent at a right angle, the posterior half straight, with at least twenty small teeth, decreasing in size gradually toward the beak; anterior half gently convex, with about thirty teeth. Considering the unusual strength of the hinge plate, the teeth are very small. Anterior and posterior muscular scars large, moderately impressed.

Compared with other species the nearest appear to be *T. astartiformis* Salter, and *T. compressa*, and *T. similis* of the present paper. From the first it is distinguished by being less ventricose, in the flattening of the dorsal edges, and in the greater number and smaller size of the hinge-teeth. The second is more compressed, and has more erect beaks, finer surface striæ, and fewer hinge teeth. The third is without the anterior sulcus, has no sharply defined posterior lunette, is higher, generally of smaller size, and has the umbones more tumid, with the point of greatest convexity above the center.

*Formation and locality:*—Upper beds of the Hudson River group. Spring Valley, Minnesota. It is here associated with *T. similis*, *T.* near *iphigenia* Billings. *Lyrodesma major* Ulrich, and an abundance of Brachiopoda. Casts of the interior, apparently referable to this species, occur in equivalent beds at Oxford, Waynesville, and other localities in Ohio.

## TECHNOPHOROUS (?) EXTENUATUS, n. sp.

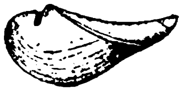


Fig. 8, *Technophorus (?) extenuatus*, n. sp. Left side of the only example, a nearly perfect cast of the interior, seen. nat. size.

Shell small, compressed, elongate, alated and drawn out posteriorly. Beaks small, erect, moderately prominent, situated about one-fourth of the entire length from the anterior extremity. Just in front of the beaks the casts of the interior exhibit a deep though not very long impression. Anterior end broad, rounded, most prominent in the upper third; ventral margin broadly convex and slightly produced a little in front of the middle; behind this point the outline is nearly straight (slightly concave) sloping up toward the narrow (? pointed) posterior extremity. Cardinal line nearly as long as the entire shell, gently concave behind the beaks. A thin, sharply defined ridge, slightly curved, extends across each valve from the beak to the lower side of the posterior end. Surface gently convex in the anterior half, marked with obscure concentric lines of growth.

Length about 21 mm., greatest height 10 mm., greatest convexity about 3.5 mm.

This is a peculiar shell, and it is with considerable doubt that I refer it to the recently proposed genus *Technophorus*, Miller (North Amer. Geol. and Pal., p. 514, 1890). I do so because in another undoubted species of the genus in my possession the posterior extremity of the hinge is drawn out in a manner similar to what we see in the present shell. The prolongation however is much less extensive in the undescribed species. Both the latter and Miller's type of the genus (*loc. cit.*) have two posterior ridges crossing each valve, and in both again the hinge line is straight.

The Cincinnati species which I called *Nuculites yoldiaformis* (Jour. Cin. Soc. Nat. Hist., vol. 2, p. 24, 1879), is probably a related form. As it is clearly not a true *Nuculites* and seemingly without any near relations to any established genus, it might be well to erect a new genus for their reception.

*Formation and locality*:—Rare in the middle third of the Trenton shales at Minneapolis, Minnesota. I am indebted to the liberality of Prof. C. W. Hall, of the State University of Minnesota for the only specimen seen.

## CLEIDOPHORUS CONSUETUS, n. sp.

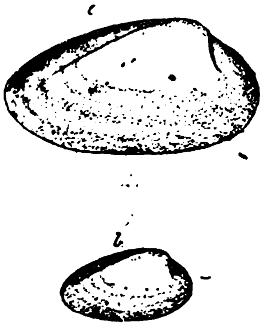


Fig. 9. *Cleidophorus consuetus*, n. sp. *a*, cast of a right valve of this species, x2; *b*, same of the natural size.

Shell above the medium size for the genus, transverse, moderately elongate, ovate, rather strongly convex, the length equaling nearly twice the height. Beaks small, incurved, flattened. Dorsal line convex, sloping downward behind the beaks to the narrowly rounded posterior extremity. Anterior end neatly rounded, wider than the posterior. Ventral margin gently convex in the middle, more strongly and almost equally curved at the ends. An obscure umbonal ridge traceable from the beaks three fourths of the distance to the posterior basal edge. Above it an impressed narrow line, beyond which the surface descends rapidly to the dorsal margin. Casts of the interior with a narrow, slightly curved, clavicular impression just in front of beaks, extending but little more than one third of the distance to the antero-basal margin. Surface of casts with a few obscure growth lines or folds. Point of greatest convexity a little above and behind the center of the shell. In a dorsal view the central half of the outline is very slightly flattened.

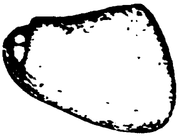
Length 17.2 mm., height 9.0 mm., thickness of both valves 5.3 mm.

This shell appears to be related to *C. cuneatus* and *C. elongatus*, described by Hall from the Silurian rocks of Nova Scotia (Can. Nat. and Geol., vol. 5, pp. 148 and 150, 1860). It is however specifically distinct, the shape being different and the posterior sinus situated higher up and very much less defined. *C. planulatus* (Conrad) and *C. ellipticus* Ulrich, also have somewhat different outlines, and have the cardinal slopes less abrupt, the whole surface in those species being more uniformly and less convex.

*Formation and locality*:—Rare in the Platystrophia horizon at the base of the Galena limestones. It is associated with *Tellinomya intermedia Ulrich*.

## MODIOLOPSIS PLANA, Hall.

*Modiolopsis planus* HALL. 1861. Report Superintendent Geol. Sur. Wis., p. 30. Geol. Wis. vol. I, pp. 38 and 438, fig. 6.



The above cut represents an internal cast of the left valve of a shell that occurs rather rarely in the upper beds of the Trenton limestones at Minneapolis and other localities in the state. There can be no question of the identity of this Minnesota form with the Wisconsin types of the *Modiolopsis plana* Hall. The latter seem to have been smaller, being said to be about three-fourths of an inch in length, but in all essential respects, our specimens agree sufficiently well with Hall's description and figure.

Among the most important features of the species is the elongate form and duplex character of the strongly impressed anterior muscular scar, the alate character of the postero-cardinal region, the length and straightness of the hinge line, and the wide truncated posterior end. The hinge also seems to have been unusually strong. In most of these respects the species approaches *M. truncata* Hall, of the Cincinnati group, more or less nearly.

These two species, together with several others, stand apart from the typical section of the genus, and should perhaps be separated under another generic name. But the whole genus *Modiolopsis* needs revision, and when this is done it will, I am satisfied, be found necessary to institute several subdivisions.

## MODIOLOPSIS SIMILIS, n. sp.

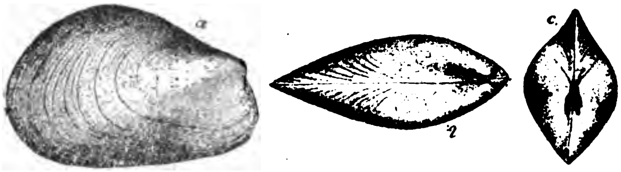


Fig. 11, *Modiolopsis similis*, n. sp. *a*, *b*, and *c*, right side, dorsal, and anterior views of a well preserved cast of the interior. nat. size.

Shell of medium size, elongate, ovate, widest in the posterior half, contracting to between one half and three fifths of the greatest width at the beaks. Hinge line nearly straight and about half as long as the shell posterior to the beaks. Anterior end small, neatly rounded; ventral margin nearly straight in the middle, curving up at the ends; posterior end broadly rounded, slightly produced in the lower half, sometimes forming an obtusely angular junction with the hinge line. Beaks nearly terminal, rather small, compressed, incurved, projecting moderately above the hinge. Surface moderately convex, most prominent along the posterior umbonal ridge, which is stronger than usual in species of this genus. Cardinal slope concave. A broad and comparatively well defined, mesial depression extends obliquely across the shell from the beak and, expanding, causes the straightening of the ventral margin.

tracted beneath the beaks, which are small, compressed, and project but little above the hinge. Height of posterior third about two and one-half times as great as at the beaks. Dorsal side gently arcuate; anterior two-thirds of ventral margin strongly concave, a fact due in a great measure to the width of the sulcus and the rapid slope of the surface included in it. Umbonal ridge slight, cardinal slope rather strongly convex. In a dorsal view the anterior half of the shell appears compressed, yet the point of greatest thickness is very near the middle of the length.

Surface marked simply with concentric lines of growth. Internal characters not observed.

This peculiar species is another of the number that I am referring to *Modiolopsis* provisionally. I place it here, first, because it seems to be related to some forms of the *M. faba* section of the genus, and, second, because I know of no other established genus that would offer a more fitting placement.

*Formation and locality:*—Upper third of the Trenton shales, about six miles south of Cannon Falls, Minnesota.

## ORTHODESMA MINNESOTENSE, n. sp.

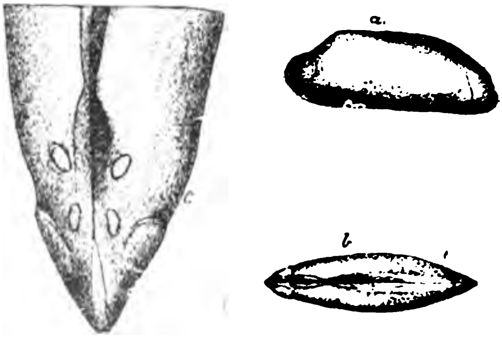


Fig. 14, *Orthodesma minnesotense*, n. sp. *a* and *b*, left side and dorsal views of a cast of the interior; *c*, dorsal view of anterior third enlarged to show the muscular scars, x4.

Shell small, elongate, subrhomboidal, with the dorsal and ventral margins nearly straight and parallel; the length two and one half times the width. Beaks small, incurved, compressed, projecting moderately above the hinge, and situated about one fourth of the entire length from the anterior extremity; posterior umbonal ridge subangular, cardinal slope abrupt, in casts of the interior with a linear impression close to and on each side of the hinge line. Anterior end small, contracted a little in front of the beaks, almost uniformly rounded; posterior convex, the anterior end semicircular, the posterior more narrowly rounded and slightly produced in the middle. Beaks small, incurved, projecting but little above the hinge, situated about one-fifth of the entire length from the anterior extremity. Umbonal ridge slight, running close to the dorsal margin, causing the central part of the dorsal side of the shell to be somewhat flattened. Sides of valves moderately convex, with point of greatest convexity a little in front of and above the middle.

Casts of the interior show a sharply defined, ovate, anterior muscular scar, which must have been bounded on the inner side by a strong internal ridge, extending downward and curving forward from the hinge, at a point just in front of the beaks, to the lower end of the muscle. The posterior scar and pallial line are not distinguishable in the material at hand. The lower and anterior parts of casts exhibit a few, obscure, broad lines of growth.

This is one of a small group of species that remind one greatly of *Cleidophorus*, Hall, to which genus they might be referred were it not for the distinct impression of the anterior muscular scar. The shape and size of the present species is considerably like that of *Cleidophorus consuetus*, described in this paper, but, aside from other differences, the one relating to the presence of a muscular scar will distinguish them at once. I know of no described species of *Modiolopsis* sufficiently resembling this to necessitate comparisons.

*Formation and locality:*—Galena shales, near Cannon Falls, Minnesota.

## MODIOLOPSIS CONCAVA, n. sp.

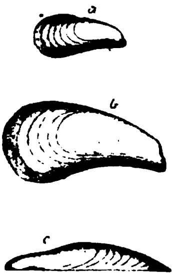


Fig. 13. *Modiolopsis concava*, n. sp. *a*, right valve of the natural size; *b*, and *c*, side and dorsal views of same, x2.

Shell very small, elongate, the greatest width less that half the length, curved, the posterior end much the widest, broadly rounded, the anterior end exceedingly short and narrow, contracted beneath the beaks, which are small, compressed, and project but little above the hinge. Height of posterior third about two and one-half times as great as at the beaks. Dorsal side gently arcuate; anterior two-thirds of ventral margin strongly concave, a fact due in a great measure to the width of the sulcus and the rapid slope of the surface included in it. Umbonal ridge slight, cardinal slope rather strongly convex. In a dorsal view the anterior half of the shell appears compressed, yet the point of greatest thickness is very near the middle of the length.

Surface marked simply with concentric lines of growth. Internal characters not observed.

This peculiar species is another of the number that I am referring to *Modiolopsis* provisionally. I place it here, first, because it seems to be related to some forms of the *M. faba* section of the genus, and, second, because I know of no other established genus that would offer a more fitting placement.

*Formation and locality*:—Upper third of the Trenton shales, about six miles south of Cannon Falls, Minnesota.

## ORTHODESMA MINNESOTENSE, n. sp.

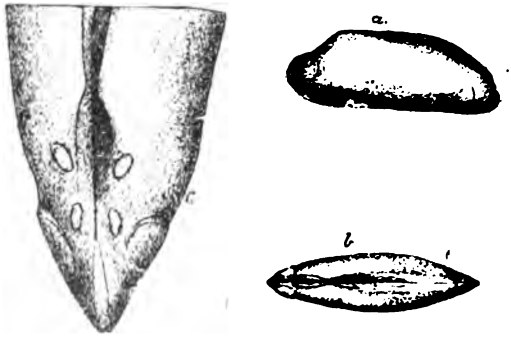


Fig. 14, *Orthodesma minnesotense*, n. sp. *a* and *b*, left side and dorsal views of a cast of the interior; *c*, dorsal view of anterior third enlarged to show the muscular scars, x4.

Shell small, elongate, subrhomboidal, with the dorsal and ventral margins nearly straight and parallel; the length two and one half times the width. Beaks small, incurved, compressed, projecting moderately above the hinge, and situated about one fourth of the entire length from the anterior extremity; posterior umbonal ridge subangular, cardinal slope abrupt, in casts of the interior with a linear impression close to and on each side of the hinge line. Anterior end small, contracted a little in front of the beaks, almost uniformly rounded; posterior end oblique, sloping upward and forward from the produced and narrowly rounded lower part.

Interior with the anterior pair of muscular scars rather distinctly marked and large; above and between them and the beaks, two other very small pairs of scars are to be seen on the specimen figured above, but the posterior muscles left no appreciable impressions. Surface of casts with a few obscure folds of growth.

This species is related to *O. curvatum* Hall and Whitfield, though more nearly approaching *O. contractum* Hall, in the general outline. It differs from both in having the posterior end narrower, and in wanting the strong wrinkles which occur on the posterior cardinal slopes of those shells.

*Formation and locality*:—Middle third of the Trenton shales. St. Anthony Park, St Paul, Minnesota.

## ORTHODESMA SAFFORDI, n. sp.

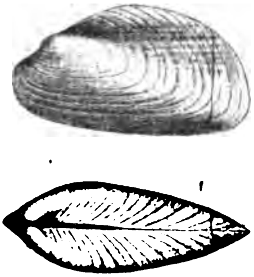


Fig. 15, *Orthodesma saffordi*, n. sp. Two views, side and dorsal, of a rather small specimen of this species, nat. size. The largest specimen seen is at least one-third larger.

Shell of medium size, elongate, trapezoidal, widest posteriorly, the length somewhat less than twice the greatest width; hinge line straight, with a narrow, concave ligamental area, extending about one-half of the entire length from the anterior extremity; ventral margin nearly straight or slightly convex, forming an angle of about 38 degrees with the hinge line. Anterior end narrow, about half as wide as the posterior part of the shell, its length equalling about one-fifth of the entire length, the outline erect above, subangular where it joins the extremity of the hinge, rounding below into the basal line. Posterior end wide, sharply curved and produced below, more gently curved and sloping forward in the middle and upper thirds, meeting the extremity of the hinge line without forming any perceptible angle. Beaks small, incurved, somewhat flattened on the umbones, projecting slightly above the hinge; umbonal ridge strong, subangular, traceable generally to the postero-basal margin; cardinal slope at first concave, gradually flattening posteriorly; with a distinct, linear sulcus running midway between the umbonal ridge and the dorsal margin, and both above and beneath this, several other, but more obscure, radiating lines may be detected; ventral slope flattened.

Surface of the shell marked strongly with rather irregular and unequal concentric lines of growth. The radiating lines on the cardinal slope have been mentioned.

One of the specimens preserves a considerable part of the hinge. It is, so far as can be seen, perfectly straight both in front and behind the beaks, and without teeth or thickenings. The ligamental area, however, is rather wide and concave. Muscular impressions unknown.

This species is wider posteriorly than any other *Orthodesma* known to me. In the general outline, excepting that the beaks are too far from the anterior extremity, and the hinge too straight, it is more like *Modiolopsis.* But it has the same kind of hinge as *Orthodesma rectum* Hall and Whitfield, the type of the genus.* The depressed line in the cardinal slope is another feature that is frequently met with, especially in the casts of species of *Orthodesma.*

It gives me much pleasure to name this fine species for Prof. Jas. M. Safford, of Nashville, Tennessee, as a slight token of my appreciation of his valuable and long continued labors in American geology.

*Formation and locality*:--In the lowest member, Safford's "Central limestone," of the Trenton formation, at Murfreesboro, Tennessee. The beds holding this fossil are equivalent to either the Chazy or the lower part of the Birdseye.

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*Hall and Whitfield say, in their generic description (Pal. Ohio, vol. ii, p. 93), that the hinge line is "contracted or bent beneath or anterior to them", *i. e.* the beaks, and this supposed feature they relied upon chiefly in distinguishing their genus from *Orthonota*, Conrad. But this supposed bending or contraction of the hinge line does not exist in *O. rectum* nor in *O. curvatum* or in any other species of *Orthodesma* known to me. The evidence bearing upon the disputed point afforded by my collections is, at any rate in the two species mentioned, unequivocal.

## CYPRICARDITES SARDESONI, n. sp.

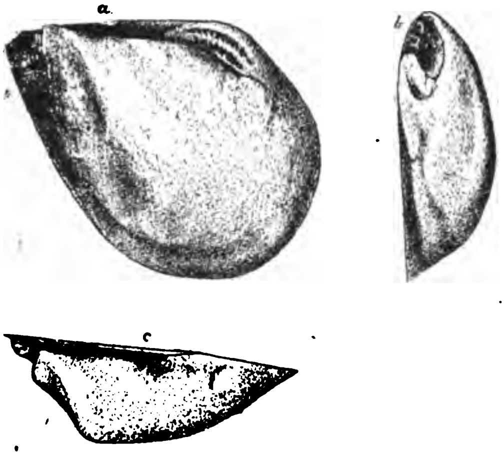

Fig. 16. *Cypricardites sardesoni.* n. sp. *a*, *b* and *c*, lateral, anterior, and dorsal views of a cast of the interior of a right valve, nat. size.

Shell of the medium size, known only from casts of the interior, and the impression of the hinge and free margins on the limestone matrix. The outline was subrhomboidal, with the cardinal and anterior margins nearly straight, and the two lines forming an angle of about 62 degrees; anterior extremity subacute or sharply rounded; hinge line equaling nearly three-fourths of the entire length; postero-ventral margin broadly rounded, almost semicircular; above this the posterior outline is somewhat straightened and slopes forward rapidly, meeting with the cardinal line to form an angle of about 135 degrees; the immediate junction however is not perceptibly angular.

In the casts the beaks project strongly, are nearly terminal, pointed, slightly incurved, greatly compressed, and somewhat twisted. A strong sulcus extends from the beaks to the antero-basal part of the cast; this sulcus occupies the larger part of the anterior slope, and from its inner side the umbonal ridge, constituting the highest portion of the surface, rises abruptly. For the reasons mentioned the anterior slope appears flattened and in part concave, while the posterior is almost uniformly convex to the margin. Cardinal slope abrupt, especially near the hinge.

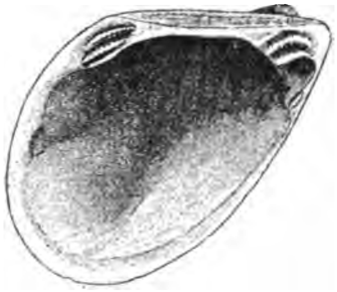

Fig. 17. Interior of left valve of *Cypricardites sardesoni*, n. sp., as shown in gutta-percha impressions.

Gutta-percha impressions, as shown in fig. 17, bring out the internal characters in a very satisfactory manner. They show a wide and faintly striated ligamental area, two lateral and two cardinal teeth, both pairs strong and distinctly crenulated on the sides. The cardinal pair are considerably curved, and the lower one forms the upper boundary of the very sharply impressed anterior muscular scar. On the whole the hinge impresses one as being unusually strong. The posterior muscular scar is large, ovate, double or prolonged below, and but faintly impressed.

I know of no associated species, nor of any now referred to this genus, that is at all likely to be confounded with *C. sardesoni*.

The specific name is given in honor of the discoverer, Mr. F. W. Sardeson, of Minneapolis, Minnesota, an enthusiastic collector and a promising student of paleontology.

## CYPRICARDITES OBTUSIFRONS, n. sp.

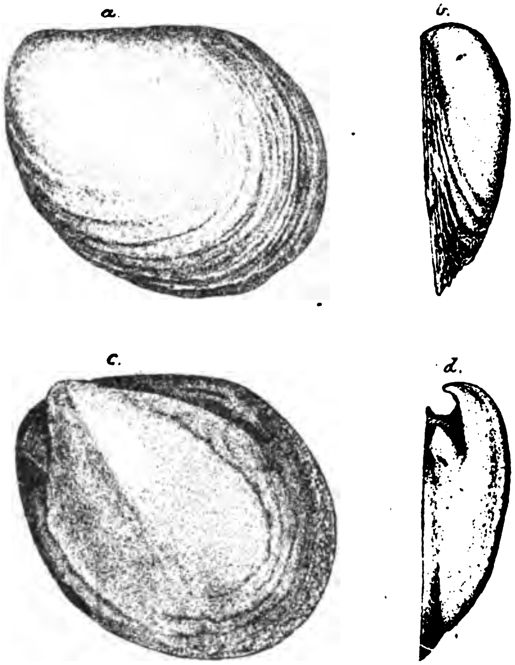

Fig. 18, *Cypricardites obtusifrons*, n. sp. *a*, and *b*, lateral and anterior views of a gutta percha impression of the exterior of a left valve; *c*, and *d*, similar views, of the cast of the interior of same shell; all nat. size.

Shell of medium size, scarcely ventricose, oblique, subovate, widest and broadly rounded posteriorly, with the beaks subterminal, small, projecting very slightly; umbonal region full, but scarcely distinguishable in the general convexity of the surface; anterior end obtuse, forming nearly a right angle with a straight hinge line, the junction between the two rounded; posterior and basal margins semicircular. Surface with the greatest convexity in the antero-dorsal third, the cardinal and anterior slopes more gently convex; surface markings consisting of rather irregular, fine and coarse, sublamellose lines of growth.

Casts of the interior with the beaks large, compressed, strongly, incurved; a moderate umbonal ridge and sulcus crosses the casts from the beaks in a direction nearly parallel with the anterior margin, becoming obsolete before reaching a point near the middle of the basal line. Anterior muscular scar deeply impressed, rather large, partly overhung by the projecting beak. Posterior scar illy defined.

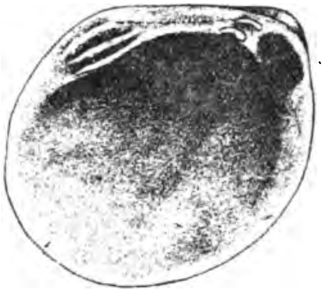

Fig. 19. View of a gutta percha impression taken from a mould of the interior of a left valve of *Cypricardites obtusifrons*, n. sp.

The gutta percha impression illustrated in fig. 19, was prepared from the cast of the interior represented by fig. 18, *c* and *d*. It shows that the hinge plate was strong, nearly flat in the central part, with three strong lateral teeth, and two small anterior cardinal teeth. Just in front and beneath the latter is the large and strongly impressed anterior muscular scar.

In some respects this species is like *C. sardesoni*, which is also associated with it in the limestone, but a comparison of the figures here given of the two species will show so many striking differences that there is really no danger of confusion between them. Some resemblance is also to be noted to species like *C. obtusus* Hall, *C. saffordi* Hall, and *C. haynianus* Safford, but they are all really quite different internally, and in having the umbones more prominent. *C. niota* Hall, occupying a similar position in Wisconsin, is likewise to be compared. It is a more erect shell, and differs in other particulars as well.

*Formation and locality:*—Collected by Prof. C. W. Hall, of the State University, in the upper beds of the Trenton limestone, at Minneapolis, Minnesota.

## CYPRICARDITES GLABELLUS, n. sp.

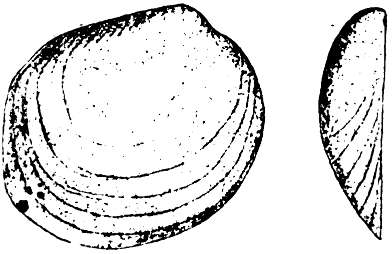

Fig. 20, *Cypricardites, glabellus*, n. sp. Lateral and anterior views of a right valve.

Shell scarcely reaching medium size, broad-ovate or subquadrangular in outline, with the back straight, the posterior margin sloping forward in the upper fifth, straightened and nearly vertical in the middle, and curving forward below into the broadly rounded ventral margin; anterior side convex, short. Beaks small, the umbonal region full, very slightly prominent, with the line of greatest convexity—not sufficiently defined to be called a ridge—extending obliquely across the valves from the beaks toward the postero-ventral edge; point of greatest convexity very near the center of the shell. Cardinal slope flat, rather abrupt; between this and the undefined umbonal ridge the surface is again slightly flattened; anterior and basal slopes gently convex. Surface nearly smooth, near the margins marked simply with a few lines of growth. Internal characters unknown.

The outline of this species is about intermediate between *C. ventricosus* Hall, and *C. niota* Hall, but the relations between them are, I am satisfied, quite remote. Both those species are at once distinguished by the greater prominence of their umbones.

*Formation and locality*: -Rare in the middle third of the Trenton shales, at Minneapolis, Minn. A cast of the interior from the "Buff limestone" at Beloit, Wis., now before me, may belong to this species.

## CYPRICARDITES CINGULATA, n. sp.

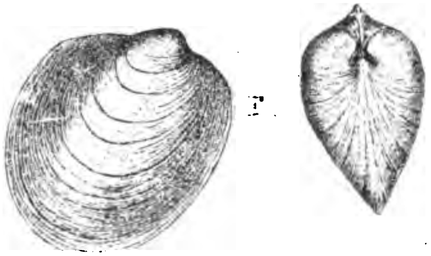

Fig. 21, *Cypricardites cingulata*, n. sp. Lateral and anterior views of a nearly perfect specimen of this species, nat. size.

Shell scarcely reaching the medium size, ventricose, oblique, the outline, excepting a slight prominence at the postero-cardinal edge, regularly ovate, but narrow anteriorly and broadly rounded posteriorly; hinge line rather short posterior to the beaks, slightly convex; beaks of good size, strongly incurved, projecting well above the hinge, situated one fifth of the entire length from the anterior extremity; umbones prominent, full, with an obtuse ridge or line of greatest altitude running from the beaks toward the postero-basal side; anterior and cardinal slopes both slightly concave, the latter descending more abruptly. Point of greatest convexity near the middle of a line drawn parallel with, and one-third of the height of the shell beneath the hinge. Surface marked with very fine concentric lines, easily abraded, and distant irregular lines or wrinkles of growth. Shell substance thin. Internal characters unknown.

This species seems to be rather closely related to *Cyrtodonta canadensis* Billings, but is more erect, comparatively higher posteriorly, and has its outline more produced and more sharply rounded in the postero-cardinal region. *C. ventricosus* Hall, is not so wide posteriorly, and on the whole has a different outline, being, besides, more ventricose. *C. grandis* Ulrich, is a larger and almost circular shell.

*Formation and locality:*—Middle third of the Trenton shales, at Minneapolis, Minnesota.

## CYPRICARDITES GERMANUS, n. sp. or var.

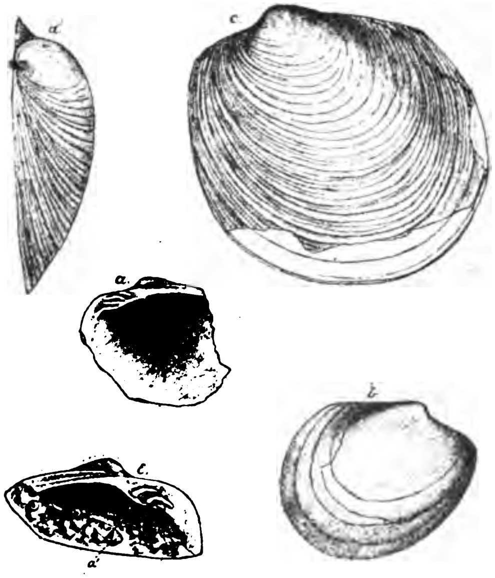

FIG. 22, *a* and *b*.

FIG. 22, *a* and *b*. *Cypricardites germanus*, nov. nom. *b*, fragment of a right valve of this species or variety, restored. nat. size; *a*, interior of same, showing the thin hinge, anterior teeth, and the faintly impressed muscular scar; *c*, *d*, and *e*, lateral and anterior views, and the greater part of the hinge of a small left valve of *Cypricardites grandis* Ulrich, from the upper Trenton near Danville, Kentucky. Introduced for comparison with *C. germanus* and *C. tenellus*.

Of this form I have several fragmentry shells, none of them better than the one above illustrated. Ordinarily, I would not consider such material as sufficient to justify description and naming, but in the present instance it has seemed right to set good custom aside. The specimens, namely, exhibit a striking departure from usual *Cypricardites* in the great projection beyond the beaks of the anterior end of the shell. In most species the anterior end is very short,—occasionally the beaks are quite terminal—but in *C. grandis* Ulrich (Amer, Geol., vol. 6, p. 387, 1890) of which a small and unusually oblique example is illustrated in fig. 22, *c*, *d*, and *e*, it is longer than in any other species heretofore described, while in the proposed *C. germanus* the projection is comparatively greater yet.

The shell in *C. germanus* is very thin, so that even the anterior muscular impression is scarcely recognizable, the hinge too is very thin, while the anterior teeth are small and drawn out to an unusual distance in front of the beaks. Excepting that the teeth are less curved and the hinge plate less expanded where they occur, the characters of the form are not greatly different from *C. grandis.* It is very likely merely a small variety of that species. Both are found in the upper beds of the Trenton near Danville, Kentucky, the small form a few feet higher in the series than the large *C. grandis.* I have seen also a number of internal casts, in the lower part of the Galena limestone and in the shales immediately beneath them, at localities in Goodhue and Fillmore counties, Minnesota, that may belong to one or the other of these forms, but they are all too illy preserved to admit of determining their relations with certainty.

## CYPRICARDITES TENELLUS, n. sp.

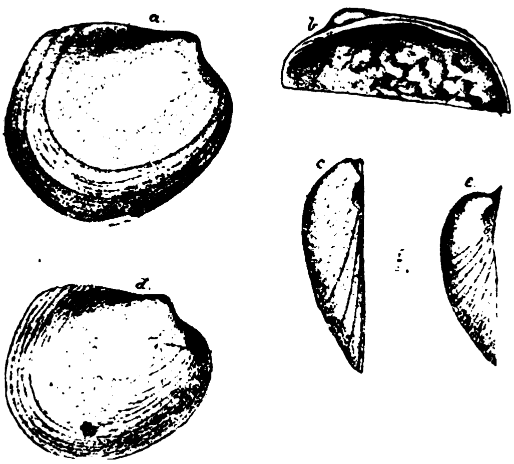

**Fig. 23.** *Cypricardites tenellus*, n. sp. *a*, right valve, with strongly marked lines of growth; *b*, hinge of same; *c*, anterior view of same; *d*, a smaller valve with finer surface markings and wider anterior end; *e*, anterior view of same; all of the natural size.

Shell of medium size or less, moderately ventricose, not very oblique, subovate, widest posteriorly, slightly alate and subangular or sharply rounded in the postero-cardinal region. Hinge line long, slightly arcuate; posterior margin straightened in the upper half, broadly rounded and produced a little in the lower half; ventral margin rather strongly convex, and most prominent a little behind the middle; anterior end more or less narrowly rounded. Beaks small, incurved, projecting moderately beyond the hinge line; situated about one-fourth of the entire length behind the anterior extremity; umbones full, prominently rounded. Cardinal slope slightly concave. Surface marked with rather fine concentric striæ, and sometimes with strong, distant lines of growth as well.

Shell substance very thin. Hinge plate almost linear when compared with the majority of the species of the genus; with two very slender posterior lateral teeth in the right valve, and probably only one in the left; anterior teeth obscure in the specimen, consisting apparently of one or two slight longitudinal folds in the margin of the shell. Muscular impressions very faint.

In this species the hingement is reduced to the minimum of strength so far noticed in the genus. It is possible that this reduction has gone beyond the just limits of *Cypricardites*, but in view of the fact that the species is approached in this respect by *C. germanus*, which, as well as several other undoubted species of the genus, as now understood, it also resembles in the general expression of its shells, it did not seem to me worthy now of greater recognition than specific.

*C. cingulata*, from a lower horizon in the shales, is a more ventricose shell, with the umbonal ridge stronger, and the outline a little different, being longer from the beaks to the postero-ventral margin, with both the anterior end and the hinge line shorter.

*Formation and locality*: - Upper third of the Trenton shales, about six miles south of Cannon Falls, Minnesota. A cast of the interior, collected by Mr. Wm. H. Scofield from the lower part of the Galena Limestone, at Wykoff, Fillmore county, probably belongs here.

## CYPRICARDITES NANUS, n, sp.

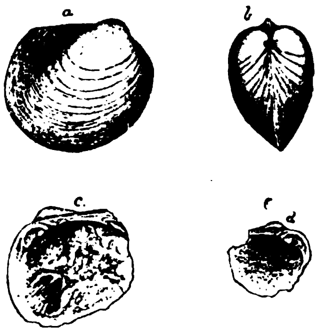

Fig. 24, *Cypricardites. nanus*, n. sp. *a* and *b*, side and anterior views of a silicified specimen, nat. size; *c*, anterior part of the hinge of a small left valve ; *d*, hinge of a right valve.

Shell small, ventricose, slightly oblique, the outline subcircular, a little the widest posteriorly, with the hinge line straight or very slightly arcuate, and the anterior end produced a little beyond the line of the circular curve formed by the posterior and ventral margins; height and length respectively as five is to six; postero-cardinal border subangular. Beaks small, strongly incurved, projecting well above the hinge; situated about one-fifth of the entire length from the anterior extremity; umbones full, prominent, with a strongly rounded ridge traceable from the beak nearly to the postero-ventral margin. Cardinal slope rather strongly concave. Surface marked with fine lines of growth. With age a few strong marginal wrinkles may be formed. Shells ubstance thin.

Hinge of moderate strength, considering the size of the shell, with two anterior teeth in each valve, the lower and forward one forming the sharp upper boundary of a narrow and horizontally extended muscular impression. Posterior teeth not well shown in the material at hand; probably two or three, and much like those of *C. haynianus* Safford.

This species is closely related to *C. haynianus* Safford, a common species of the Trenton of Kentucky and Tennessee, but is smaller, more ventricose, with the outline more nearly circular, the beaks less nearly terminal, the umbonal ridge stronger, and the shell thinner. It has also only two instead of three or more anterior hinge teeth. None of the other species known to me are very closely related.

A similar, though not a strictly identical species, is indicated by a cast of the interior, collected by Mr. Wm. H. Scofield, at

Wykoff, in Fillmore county of this state, where he found it at the base of the Galena limestone. This cast belonged to a larger shell than has been noticed of *C. nanus*. Its outline is also a little different, being too wide posteriorly, and more sharply curved at the postero-basal border, while the beaks are more nearly terminal. In short, the outline is more nearly like that of *C. haynianus* (see fig. 25*b*), slightly longer, perhaps, but I am satisfied that it is distinct from Safford's species, having obviously been formed by a thinner shell in which the internal ridge, which is always present in his species, was absent or, as is the case with *C. nanus*, too illy defined to leave a certain mark on the casts.

*Formation and locality:*—The nine, more or less defective specimens of this species contained in my cabinet, were collected from the upper beds of the Trenton, in Mercer county, Kentucky.

## CYPRICARDITES HAYNIANUS (?) Safford.

*Cyrtodonta hayniana* SAFFORD, 1869. Geol. Tenn., pl. F., fig. 1.

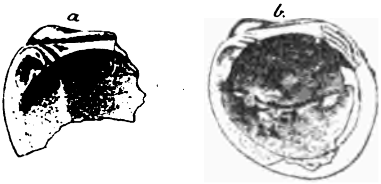

Fig. 25. *Cypricardites haynianus* Safford. Upper Trenton, near Danville, Kentucky; *a*, a well preserved fragment of a right valve, showing the anterior part of the hinge, with its teeth, the muscular impression, and the internal ridge; *b*, the interior of a smaller right valve with the anterior teeth disposed more horizontally than usual in this species.

I am nearly convinced that this species is represented in the Galena shales of Minnesota, but all of the specimens seen by me are internal casts, and none of these are sufficiently well preserved to permit an unequivocal determination of their relations. The internal ridge and the compressed beaks (they are concave on the inner side) required by casts positively known to belong to the species, are determinable in some of the specimens, but each of these is either incomplete or has suffered compression in the shales, so that the original shape of the shells is left in doubt. Under the circumstances I thought it well to call the attention of Minnesota collectors to the forms, in the hope that some of them may find better specimens.

Among some lamellibranch shells received from Mr. Wm. H. Scofield, there is a fragment of a *Cypricardites* that he obtained from the upper third of the Trenton shales, at the locality six miles south of Cannon Falls that has furnished so many interesting shells of this class. This specimen consists of the anterior third of the shell itself, showing about half of the hinge with three anterior teeth and a muscular impression beneath them. Every point that is preserved corresponds so nearly with fig. 25 *a*, that it would surprise me greatly if it turned out to be distinct from *C. haynianus*.

## MATHERIA RUGOSA, n. sp.

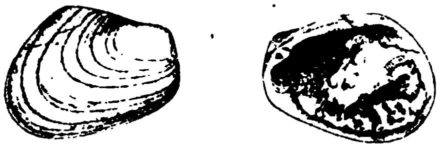

Fig. 26, *Matheria rugosa*, n. sp External and internal views of the only specimen seen, nat. size. The posterior part of the hinge is broken away and that portion of the figures is to be regarded as a restoration.

Shell large for the genus, trapezoidal, widest posteriorly, with the beaks nearly terminal, small, incurved, projecting slightly above the hinge; a strongly convex umbonal ridge. Anterior end descending abruptly from the beaks, below rounding sharply into the nearly straight ventral border; posterior margin produced and strongly rounded in the lower half, obliquely subtruncate above and probably forming an obtuse angle at the junction with the hinge line; the latter very gently arched. Surface marked with strong, concentric wrinkles, and finer lines of growth. Shell substance of moderate thickness.

Hinge plate strong, flat, slightly arcuate, the upper half of the width, posterior to the beaks, finely striated lengthwise. Cardinal teeth small, situated just beneath the beaks, directed toward the postero-basal margin, with one in the right valve and, on each side of it, a deep socket for the reception of the two teeth of the left valve. Anterior muscular scar rather distinct, subcircular, situated immediately beneath the teeth. Posterior extremity of hinge wanting in the specimen, probably without teeth.

This species is almost certainly a true *Matheria*, a genus described by Billings for a single species occuring in the Trenton rocks of Canada and Kentucky, and which he called *M. tener*.*

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*Can. Nat. and Geol., vol. 3, p. 440, 1858.

Several other species, as yet undescribed, are known to me from the same rocks in Kentucky, but all are smaller and less wide posteriorly. *M. tenera* has the dorsal and ventral margins nearly parallel.

*Formation and locality:*—Upper third of the Trenton shales, six miles south of Cannon Falls, Minnesota.

## ISCHYRODONTA OVALIS, n. sp.

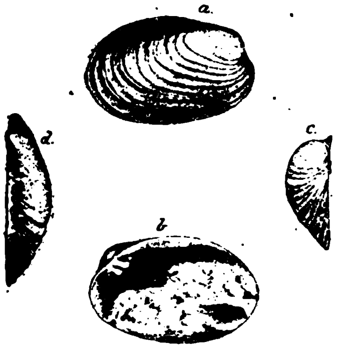

FIG. 27, *Ischyrodonta ovalis*, n. sp. *a*, and *b*, external and internal views of a right valve; *c*, and *d*, anterior and cardinal views of the same; nat. size.

Shell small, moderately ventricose, almost regularly elliptical in outline, with the greatest width and thickness midway between the ends; width and length about as two is to three. Beaks small, situated near the anterior extremity, compressed by a flattening of the surface which, expanding, extends over the greater part of the ventral slope. Edges of valves meeting at the center of the ventral margin, apparently gaping a little at the ends. Umbonal ridge prominently rounded, cardinal slope abrupt, very little concave. Surface marked with strong lines of growth and a few finer concentric striae, both inclining to be irregular.

Hinge plate arcuate, widening posterior to the beaks, grooved as for the reception of an internal ligament. Cardinal teeth two, projecting downward and backward from the hinge plate, which is thin at this point, and supported by an internal process that seems to extend up into the cavity of the beak, and projects on each side of the teeth so as to give the whole the appearance of a quadrifid tooth. Anterior muscular scar rather small, occupying the anterior extremity of the shell.

This species is not strictly congeneric with the types of *Ischyrodonta* (Amer. Geol., vol. 6, pp. 173-175), but there is no other established genus known to me offering a closer agree ment, and before I can consider the erection of a new genus as fully justified, I wish to see the main peculiarties of the shell confirmed in other species. The uncertainty of the position of the species is increased by the fact that it might be referred, with equal propriety perhaps, to the genus *Matheria*, of Billings. I infer therefore that we are dealing with an undescribed generic type having somewhat intermediate relations between *Matheria* and *Ischyrodonta*.

*Formation and locality:*—At present known only from Richmond, Indiana, where it was fonnd in the upper beds of the Cincinnati group. Equivalent strata are exposed in the vicinity of Spring Valley, Minnesota.

## PLETHOCARDIA, n. gen.

(*Pletho*, to be full; *kardia*, heart, in allusion to the shape of the closed valves.)

Shell thin, inequilateral, oblique, tumid, with the margins closed; beaks large, prominent, spirally enrolled, and curving forward. Cardinal margin, posterior to the beaks, with a narrow, but deep escutcheon or lunette. A strong and large, bifid, cardinal tooth projects forward and downward from the thin edge of the straight hinge plate; one strong linear, lateral tooth, or thickened internal cartilage support, beneath the posterior extremity of the hinge line, and close to the margin. Anterior muscular scar strongly impressed, situated in the antero-dorsal angle, margined on the inner side by a curved ridge extending from the under side of the cardinal tooth. In casts of the interior the filling of the anterior impressions forms a small but sharply defined lobe. Posterior muscular scars and pallial line unknown. Type: *P. umbonata*, n. sp.

The shells of this genus present considerable external resemblance to those of *Whitella*, Ulrich. As a rule they will probably prove shorter, more erect and comparatively more ventricose. I believe also that *Whitella* offers closer affinities than any other genus yet known, and I can see that it may prove difficult in some cases to distinguish species of the two genera, when the internal characters are not available. Of course, such difficulties cannot obtain when the diagnostic characters of the hinge are preserved, since the strong cardinal tooth of *Plethocardia* is too marked a feature to be overlooked in comparing the two genera. Good casts of the interior even are easily distinguished by the presence of the small lobe beneath and in front of the beaks of *Plethocardia*, the muscular impressions being very much less distinct in the casts of *Whitella*. In the posterior part of the hinge, however, the two genera are practically the same.

It is possible that this genus represents an early type of those heavy and otherwise peculiar shells which Zittel has embraced in his family *Megalodontidæ*. A general resemblance is to be noted yet I doubt very much that any true relationship existed between them.

## PLETHOCARDIA UMBONATA, n. sp.

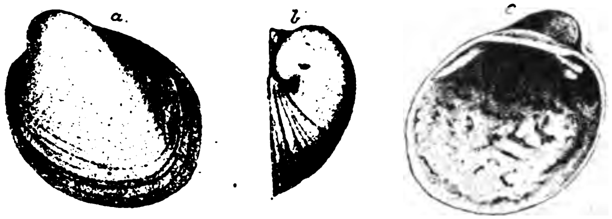

Fig. 28, *Plethocardia umbonata*, n. sp. *a* and *b*, lateral and anterior views of a left valve; *c*, inner side of same, showing the escutcheon, the bifid cardinal tooth, anterior muscular impression, and the internal ridge-like thickening of the shell just within the postero-dorsal border; natural size.

Shell rather small, moderately oblique, strongly ventricose, widest posteriorly, subovate in a side view. Beaks large, very prominent, inrolled; umbonal ridge angular, traceable to the postero-basal margin. Cardinal slope narrow, rather sharply defined, concave. Anterior end very short, nearly vertical, rather sharply rounded above; dorsal margin arcuate, graduating into the posterior curve; the latter is produced slightly in the lower part and quickened as it turns into the broadly convex ventral margin. Surface marked with concentric lines of growth, some of them strong.

Escutcheon narrow, extending backward from the beaks nearly to the posterior extremity of the hinge. Cardinal tooth large, bifid, projecting obliquely forward from the lower side of the hinge line. A strong, ridge-like thickening of the shell, probably representing the support of an internal ligament, occurs just within the postero-cardinal margin. Anterior muscular scar situated in a cup-like depression formed by a curved ridge which proceeds from the underside of the cardinal tooth, and the antero-cardinal margin of the shell.

It is possible that this species is not distinct from the *Cyrtodonta cordiformis* of Billings. His figures of that species look so much like the Minnesota shell above described that I am nearly satisfied that they must be congeneric at least. It might be a

*Whitella* but it is not a true *Cypricardites*. Compared with *P. umbonata* it appears that in the Canadian shell the beaks are situated farther back from the anterior extremity, the umbonal ridge is rounded instead of angular and the outline different, especially that of the posterior end, which is also wider.

*Formation and locality:*—Upper third of the Trenton shales, six miles south of Cannon Falls, Minnesota. Collected by Wm. H. Scofield.

## PLETHOCARDIA SUBERECTA, n. sp.

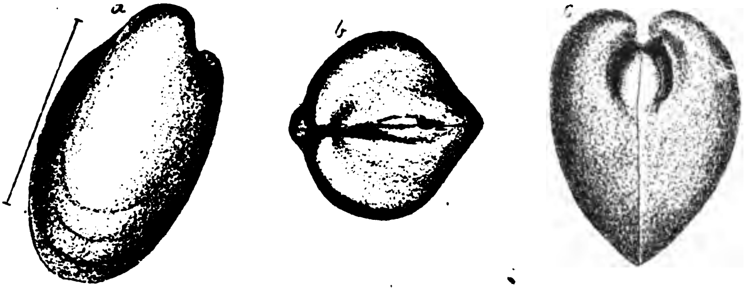

Fig. 29. *Plethocardia suberecta*, n. sp. *a*, *b*, and c lateral, dorsal, and anterior views of a cast of the interior; natural size.

Shell small, but little oblique, exceedingly ventricose, short, subelliptical in a side view, with the dorso-ventral diameter much the longest. Beaks very prominent, large, strongly incurved, nearly terminal, umbonal ridge strong, sharply rounded, with the cardinal and posterior slopes very abrupt, and nearly flat. Anterior end very short, the part in front of the beaks of casts consisting chiefly of the sharply defined, lobe-like filling of the anterior muscular impressions. Anterior and posterior margins gently convex, subparallel; ventral edge sharply rounded. Hinge line short, scarcely extending posterior to the umbonal ridge, as seen in a side view. In the casts there is a depression beneath the beaks that is prolonged on each side around the muscular scar. The escutcheon seems to have been narrow, but the internal ligament supports at the posterior end of the hinge line have left two strong grooves, one on each side.

This species, though clearly congeneric with *P. umbonata*, is so readily distinguished from that species that comparisons are unnecessary,

*Formation and locality:*—Galena shales, near Cannon Falls, Minnesota.

posterior part of the hinge, however, the two genera are practically the same.

It is possible that this genus represents an early type of those heavy and otherwise peculiar shells which Zittel has embraced in his family *Megalodontidæ*. A general resemblance is to be noted yet I doubt very much that any true relationship existed between them.

## PLETHOCARDIA UMBONATA, n. sp.

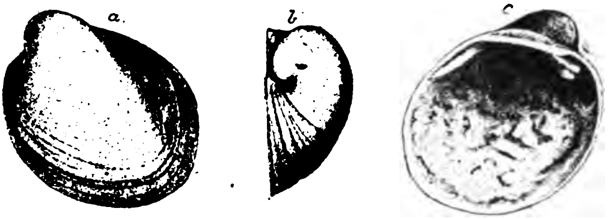

Fig. 28. *Plethocardia umbonata*, n. sp. *a* and *b*, lateral and anterior views of a left valve; *c*, inner side of same, showing the escutcheon, the bifid cardinal tooth, anterior muscular impression, and the internal ridge-like thickening of the shell just within the postero-dorsal border; natural size.

Shell rather small, moderately oblique, strongly ventricose, widest posteriorly, subovate in a side view. Beaks large, very prominent, inrolled; umbonal ridge angular, traceable to the postero-basal margin. Cardinal slope narrow, rather sharply defined, concave. Anterior end very short, nearly vertical, rather sharply rounded above; dorsal margin arcuate, graduating into the posterior curve; the latter is produced slightly in the lower part and quickened as it turns into the broadly convex ventral margin. Surface marked with concentric lines of growth, some of them strong.

Escutcheon narrow, extending backward from the beaks nearly to the posterior extremity of the hinge. Cardinal tooth large, bifid, projecting obliquely forward from the lower side of the hinge line. A strong, ridge-like thickening of the shell, probably representing the support of an internal ligament, occurs just within the postero-cardinal margin. Anterior muscular scar situated in a cup-like depression formed by a curved ridge which proceeds from the underside of the cardinal tooth, and the antero-cardinal margin of the shell.

It is possible that this species is not distinct from the *Cyrtodonta cordiformis* of Billings. His figures of that species look so much like the Minnesota shell above described that I am nearly satisfied that they must be congeneric at least. It might be a

*Whitella* but it is not a true *Cypricardites*. Compared with *P. umbonata* it appears that in the Canadian shell the beaks are situated farther back from the anterior extremity, the umbonal ridge is rounded instead of angular and the outline different, especially that of the posterior end, which is also wider.

*Formation and locality*:—Upper third of the Trenton shales, six miles south of Cannon Falls, Minnesota. Collected by Wm. H. Scofield.

## PLETHOCARDIA SUBERECTA, n. sp.

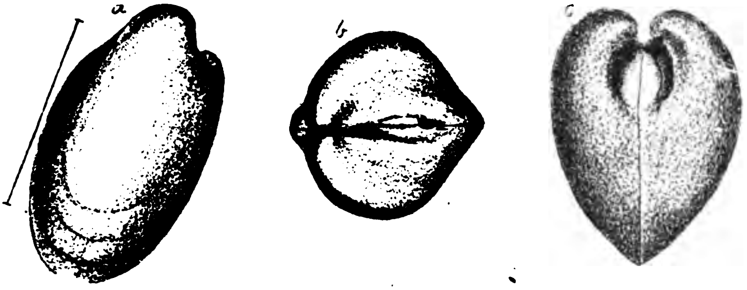

Fig. 29. *Plethocardia suberecta*, n. sp. *a*, *b*, and c lateral, dorsal, and anterior views of a cast of the interior; natural size.

Shell small, but little oblique, exceedingly ventricose, short, subelliptical in a side view, with the dorso-ventral diameter much the longest. Beaks very prominent, large, strongly incurved, nearly terminal, umbonal ridge strong, sharply rounded, with the cardinal and posterior slopes very abrupt, and nearly flat. Anterior end very short, the part in front of the beaks of casts consisting chiefly of the sharply defined, lobe-like filling of the anterior muscular impressions. Anterior and posterior margins gently convex, subparallel; ventral edge sharply rounded. Hinge line short, scarcely extending posterior to the umbonal ridge, as seen in a side view. In the casts there is a depression beneath the beaks that is prolonged on each side around the muscular scar. The escutcheon seems to have been narrow, but the internal ligament supports at the posterior end of the hinge line have left two strong grooves, one on each side.

This species, though clearly congeneric with *P. umbonata*, is so readily distinguished from that species that comparisons are unnecessary.

*Formation and locality*:—Galena shales, near Cannon Falls, Minnesota.

## WHITELLA PRÆCIPTA Ulrich.

*Whitella præcipta* ULRICH, 1890. The American Geologist, vol. vi, p. 386.

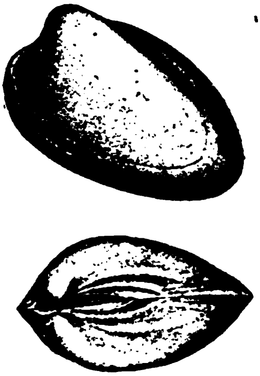

Fig. 30, *Whitella præcipta* Ulrich. Lateral and cardinal views of a cast of the interior; nat. size.

Shell of medium size, ventricose, very oblique, elongate-ovate, or subrhomboidal in a side view, produced and sharply rounded in the postero-basal region. Beaks of moderate size, prominent, strongly incurved, umbones full; umbonal ridge well marked, traceable almost to the posterior extremity. Anterior end small, very short, narrowly rounded; ventral margin gently convex; posterior end produced and narrowly rounded in the lower part; from the point of greatest extension to the posterior side of the projecting umbones, the outline is gently and almost uniformly convex. Hinge line comparatively short, its length less than half the length of the shell, the edge inflected to form a distinct escutcheon, extending somewhat in front of the beaks. In casts of the interior the internal cartilage supports have left distinct impressions of unusual width, on each side and behind the impression produced by the escutcheon. A low and obscurely defined ridge is also to be seen running through the middle of the cardinal slope. Anterior muscular scar faint, subovate, acuminate below, situated very near the anterior extremity. Pallial line represented by a thin raised line, running near and parallel with the margin of the cast. It can be traced from the anterior scar to the impressions of the internal ligament supports.

This species is very similar to *W. obliquata* Ulrich, from the upper beds of the Cincinnati group, yet I do not doubt that they are really quite distinct species. That species grows to a larger size, is less elongate, wider posteriorly, with the beaks and umbones smaller, and the anterior end larger. The impressions of the internal ligament supports also are very much less distinct.

*Formation and locality:*—Galena shales, near Cannon Falls, Minnesota.

## WHITELLA CONCENTRICA, n. sp.

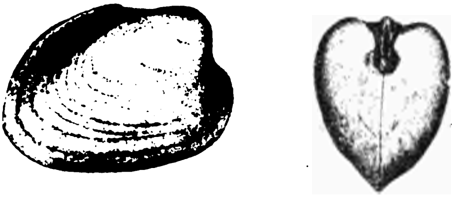

Fig. 31, *Whitella concentrica*, n. sp. Lateral and anterior views of a cast of the interior, nat. size. The beak of the left valve has been restored.

Shell rather beneath the medium size, oblique, ventricose, widest posteriorly, trapezoidal; beaks large, prominent, incurved; umbones full, with a sharply rounded ridge or line of gibbosity extending backward from the beaks to the posterior extremity of the shell. Anterior end short, narrowly rounded; ventral edge very gently convex; posterior end produced and sharply rounded in the lower half, more gently convex and sloping forward rapidly above, merging gradually into the curve of the dorsal side. Cardinal and posterior slopes slightly concave. Hinge line about half as long as the shell, with the edge inflected so as to form a narrow escutcheon, extending but little if at all in front of the beaks. Internal ligament supports leave a distinct impression on each side of the postero-cardinal margin in casts of the interior. Anterior muscular scars distinct though faintly impressed, situated in the antero-dorsal angle. Surface of casts, especially in the lower and posterior parts, marked with fairly distinct, rounded, concentric folds.

The concentric marks of growth are stronger in this species than in any other known to me. It is shorter than *W. præcipta* more ventricose than *W. compressa*, and has much fuller umbones than *W. obliquata*.

*Formation and locality.*—Middle third of the Trenton shales, at Minneapolis, Minnesota

## CUNEAMYA SULCODORSATA, n. sp.

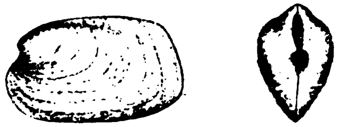

Fig. 32. *Cuneamya sulcodorsata*, n. sp. Lateral and anterior views of the type specimen. nat. size.

Shell small, moderately convex, oblong, subquadrate, with the dorsal and ventral margins subparallel and gently convex, the posterior end truncate, very slightly produced and sharply rounded, almost angular at the base; anterior end very short, narrowly rounded. Beaks subterminal, full, decumbent, strongly incurved, projecting forward rather than upward: umbonal ridge moderately prominent, not angular. Dorsal slope with a distinct, expanding sulcus; ventral and anterior slopes gently and uniformly convex. Hinge line posterior to the beaks long, the edge inflected so as to form a well-marked escutcheon. In front of and beneath the beaks a deep lunule. Surface marked with regular, concentric folds, obsolete on the cardinal slopes, and by two or three times more numerous fine striæ, which seem to have extended over all parts of the surface.

This neat shell, though seeming to be a true species of *Cuneamya*, cannot be confounded with any species of the genus so far described.

*Formation and locality.*—At the top of the Hudson River group, Spring Valley, Minnesota.

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# THE GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA.

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*The Twentieth Annual Report, for the Year 1891*

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From

N. H. WINCHELL,

*State Geologist.*

May 3. '93

---

MINNEAPOLIS:
HARRISON & SMITH, PRINTERS.
1893.

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# ERRATA.

On page 10, after the footnote add *A. Irving*, ***Metamorphism** of **Rocks**, page 96.*

On page 16, 16th line from top, for "structure of crystallines rocks" read structures of crystalline rocks.

On page 17, under "Remarks," eighth line from the top, for "No. 1" read No. 4.

On page 68, fourth and eighth lines from the bottom, for "539" read 538.

On page 88, last line, before "T. 66-5" insert 22.

On page 138, sixth line from top, strike out "V."

On page 184, line 6 from top, after "interior" insert *of the continents.*

On page 185, line 17 from bottom, for "Ontario, Erie and Huron," read *Ontario.*

On page 188, line three from top, for "Goulai's," read *Goulais.*

On page 191, line one from top, for "labradorite" read *plagioclase.*

On page 191, line ten from top, for "altitude" read *attitude.*

On page 192, line five from top, for "oragraphic" read *orographic.*

On page 192, line nineteen from bottom. for "material" read *natural.*

On page 193, line twenty from bottom, for "canals" read *vents.*

On page 193, line seventeen from top, for "all" read *mostly.*

On page 194, line seven from top, for "this" read *the.*

On page 196, line fifteen from top, for "impossible" read *possible.*

On page 196, line nineteen from top, omit "protecting."

On page 201, line five from bottom, after "It is not" insert *infrequently.*

On page 202, line one from top, for "indentation" read *indentations.*

On page 203, line nineteen from bottom, for "embankment" read *embayment.*

On page 215, line fifteen from bottom, for "time" read *line.*

On page 216, line sixteen from top, for "Of the two" read *Of two.*

On page 217, in title of Fig. 1, for "Keewenian" read *Keweenian.*

On page 223, line 14 from bottom, for "fallen" read *full.*

On page 226, line eleven from top, for "terraces" read *terranes.*

On page 233, line thirteen from top, omit "[See Pl. X., Fig. 2]."

On page 234, line twenty-one from top, for "plane" read *plan.*

On page 236, line three from bottom, for "aerial" read *a real.*

On page 238, line twenty-two from top, for "in" read *on.*

On page 241, line six from top, for "leads" read *levels.*

On page 242, line nineteen from top, for "XXI." read *XI.*

On page 250, line two from bottom, for "339.7" read *439.7.*

On page 252, line sixteen from bottom, after "cave of the" insert *embayment.*

On page 252, line nine from bottom, for "dents" read *strands.*

On page 253, line four from top, for "thickened" read *thicker.*

On page 270, at bottom of cut, insert "Fig. 11."

On page 271, line three from top, for "build" read *built.*

On page 271, line twenty-one from bottom, for "and gravel" read *gravel.*

On page 273, line twenty from top, for "gravel" read *finest.*

On page 277, line thirteen from top, for "rigid" read *ridged.*

On page 281, line eleven from bottom, for "benches" read *beaches.*

On page 284, line fourteen from top, for "altitude" *attitude.*

On page 289, line five, from bottom, for "altitude" read *attitude.*

# ADDRESS.

MINNEAPOLIS, May 1, 1892.

*To the President of the University:*

DEAR SIR.—Herewith is transmitted the twenthieth annual report of the Geological and Natural History Survey, of which I have charge. This marks the close of the second decade of my connection with this work, which began with the commencement of the survey in 1872. It is with some satisfaction that I can look over the work of the last twenty years, and with some regret that I can see its deficiencies. As a State enterprise, however, the Minnesota survey is unique in its plan, its supervisory auspices, its slow but uninterrupted progress, and in the duration of its personal directorship.

Ten years ago, in the submission of my tenth annual report, I ventured to congratulate the University and the State on the success which had attended the survey at that date, but the second ten years have been more prosperous than the first ten. Therefore, while renewing my congratulations, I think it is safe to bespeak for the third decade as great and, perhaps, greater advance in all the channels of scientific research ordered by the law. The University of Minnesota has a golden opportunity to place herself far in the van of progress in science among such institutions in America, and the overseers of the survey, as they are also overseers of the University, cannot fail to see the ways and means for bringing about such a result.

Respectfully submitted,

N. H. WINCHELL,

State Geologist and Curator of the General Museum.

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# REPORT.

SUMMARY STATEMENT. The funds of the survey, derived almost wholly hitherto from sales of the Salt Spring lands, not only became exhausted, on account of increased expense of exploration in the northern part of the state, but indebted to the University fund proper for advances to the amount of about fifteen thousand dollars. The Legislature of 1887 made a cash appropriation, of ten thousand dollars for certain economic researches, and that with some aid from the Salt Spring fund kept the field work going for four years, i. e. till the report on the iron ores of the state (Bulletin No. VI.) was published. The Legislature of 1891 made another cash appropriation for the survey amounting to fifteen thousand dollars, with a view of cancelling, in part at least, the deficit in the funds and of carrying forward the field-work toward completion. In the meantime the iron ore interests have rapidly developed, and it has become incumbent on the survey to make much closer examination into the geographic distribution of the rocks carrying this ore, as well as into many questions relating to their geology. While it has been purposed to enter at once on the preparation of the final report on the geology of the northern part of the state, it is found to be judicious to prosecute further field-work there. Large public and private interests are involved in the developments taking place. It would be discreditable to stop the survey short of satisfactory completion while such important economic results are dependent on a knowledge of the rocks carrying this iron ore. The season has been spent therefore in further field examinations and especially on the Mesabi iron range. Mr. U. S. Grant was at work on the eastern end of the range, and his (accompanying) report shows some of the results of his field-work. Mr. H. V. Winchell was directed to make a general economic study of the entire range, and to carry his data and statistics to as late a date as possible. His report therefore owing to lateness of publication laps over into the year 1892. The same season

(1891) Dr. A. C. Lawson, late of the Canadian geological survey, was employed to make a survey of the elevated beaches of the north shore of lake Superior, and incidental to that to make such study of the rock formations as his opportunities afforded. His interesting report on the beaches accompanies this, and two other supplementary papers by him are to be included in a separate publication—probably Bulletin IX.

Renewed activity also has been given to paleontological work on the Trenton and Hudson River fossils. Mr. Chas. Schuchert made a collecting tour in Wisconsin and in Iowa, and in southern Minnesota, and was engaged to assist in the preparation of chapters for the Paleontology of the state, while Mr. E. O. Ulrich continued his work on the Bryozoa. In all the paleontological work the survey has been aided gratuitously by Mr. W. H. Scofield, of Cannon Falls. The printing of Vol. III, of the final report, as outlined in the "Summary statement" for the seventeenth annual report, is now going forward.

It was thought best to divide the report of Mr. Herrick on the Mammals of the state into two parts, and to issue them separately as bulletins (VII and VIII). The first part, embracing the popular and semi-technical descriptions, is now in press, and when issued will constitute an interesting publication of the survey. The other portion is in Prof. Herrick's hands, and when it has been revised by him, and changed so as to comport with the advances made since the volume was first tendered for publication, it will appear as another bulletin of the survey. The report of Dr. Hatch on the Birds of the state is intended for similar publication, but it is not at hand. Dr. Hatch left the state about a year ago and has never actually put his manuscript in the custody of the survey. His present address is unknown.

Since the last summary statement the nineteenth report has been issued and distributed. The library of the survey gradually grows. Our reports are sent in exchange to all parts of the world. The list of additions by this means shows this growth. There is also herewith presented a statement of registrations in the museum, now reaching 8,441.

# I.

# THE CRYSTALLINE ROCKS,

## SOME PRELIMINARY CONSIDERATIONS AS TO THEIR STRUCTURES AND ORIGIN.

N. H. WINCHELL.

Sufficient field-work has now been done on the crystalline rocks of the state to enable us to enumerate the formations which they contain, and to express with some confidence the stratigraphic relations which they bear to one another. These important preliminary steps, having been taken with care and thoroughness, there remains the task to deduce from the facts ascertained some further principles of taxonomic geology and of genetic derivation for the rocks themselves.

In attempting to present these facts of the geology of the lake Superior region in such a manner as to indicate some general truths which may serve as guides for classification and nomenclature, it is the desire of the writer to acknowledge that he has been but one among several recent factors that have helped to bring some system out of confusion and chaos. After the report of Foster and Whitney in 1851, on the mineral lands of the lake Superior region, in which it was maintained that it was impossible to divide the crystalline rocks into any systematic, consistent order of succession, either stratigraphic or chronological, there have been numerous geologists who, having made examinations in one part or another of the lake Superior region, have shown that the crystalline rocks are susceptible of stratigraphic subdivision, and have attempted to express such subdivision. Generally they have shown that it is possible to separate them into two parts. This binary classification was really instituted prior to the work of Foster and Whitney by Alexander Murray and Sir William Logan of the Canadian survey. While the Canadian survey itself has tenaciously held to this simple classification, some of its individual members have, unwittingly sometimes, but intentionally at other times, put on record important facts that have called attention to inconsistencies, and to the confusion that has resulted, and some of them have in a measure abandoned the original nomenclature of Murray and Logan, and have instituted new names to express subdivisions that are needed and which were not recognized by Murray and Logan.

On the other side of lake Superior, the state surveys of Michigan and Wisconsin, while adding many and interesting facts to the general fund of knowledge of the crystalline rocks, have added but little to the advancement of their special taxonomy, or their genetic relationships. These surveys were mainly occupied with the discovery of their geographic areas, and the delineation of their local details of stratigraphy and outcrop. They adopted, in general, the stratigraphic principles and the nomenclature of the Canadian survey of 1857, but also showed that it was necessary to institute many minor distinctions in stratigraphy—without, however, attempting to establish any certain order for all the distinctions which they recorded.

It is evident that before any inquiry can be entered upon as to the more minute internal relations of these formations, it is essential that the serial order which thay sustain to each other, at least some of their grand stratigraphic taxonomy, shall be determined. To the solution of these problems very much time has been given, both by members of the United States geological survey, and by those engaged on some of the state surveys. An essential concord has been reached by the more recent investigators on some of the main questions of relationship, as well as some of the minor stratigraphic details. While the statements of this paper will be based on facts developed in Minnesota, it cannot be questioned that the principles involved, and many of the facts on which they are based will be found duplicated with equal or greater clearness, in Wisconsin and Michigan, as well as in Canada. The great synclinorium of the lake Superior valley seems to have been wrought out in a series of strata of very old date, and it manifests its concordant history in the plications and duplications of its rocky rim on all its sides alike.

The principal rock terranes, as made out in the region northwest from lake Superior are as follows:

1. A series of alternating fragmental and eruptive beds, known as Nipigon or Keewenawan, the upper portion composed almost netirely of red sandstones, placed unconformably beneath a later

series of conglomerates and sandstones in which is found the "Dieklloeephalus fauna" of the primordial.

2. Lower down are found alternating beds of "eruptive" sheets and fragmental rocks, but the fragmental are quite different from those in No. 1, being thin-bedded slates, often black siliceous and actinolitic schists, magnetitic jaspers, quartzytes and cherty quartzytes. These are interbedded with sheets of eruptive rock or rock composed of pyroclastic materials which were probably of tufaceous origin, presenting more or less evident sedimentary structures.

3. The eruptive facies is intensified at this horizon by the protrusion of immense quantities of true basic eruptive (gabbro) which is found to have embraced in itself considerable masses of the next older strata, particularly of the Pewabic quartzyte and its modifications. This gabbro is intimately associated with acid eruptive rocks of cotemporary date, constituting red felsytes, quartz porphyries and reddish granites. This gabbro is the bearer of large quantities of titanic magnetite, and very often the underlying quartzyte, involved in the gabbro, is also highly charged with magnetite, though never titaniferous.

4. The bottom of the Animikie is characterized by a great quartzyte associated with iron ores and cherts, which, however, do not always appear in their typical characters at this horizon. Associated with this quartzyte, and with some of the beds immediately overlying it, are the important iron deposits of the "Mesabi range." This quartzyte lies unconformably on all the older rocks, but principally it has been examined in its contact with the granite and greenstone of the Giant's range. Wherever its lower beds are found exposed they are apt to be conglomeritic with debris from the underlying formations. This has been styled Pewabic quartzyte. It is subject to great lithologic variations, due on the one hand to admixtures of mechanical debris from the older rocks, and on the other to chemical precipitations in the ocean in which it was gathered, and to the mingling of volcanic tuff from the eruptions that were coincident with its deposition, some of which are seen as interbedded sheets of cotemporary date. Its color is usually gray, but on the Mississippi river, at Pokegama falls, it is superficially red to the depth of two or three inches, and still further southwest, in Pipestone county, it is extensively changed to a red color. Its grains are coarse, rounded and evident, but they are joined, generally, into a compact mass by the deposition of secondary silica. In the near vicinity of the cotemporary volcanic disturbances its grain is very fine, like jaspilyte, and in some cases it has acquired a dense crystalline structure from contact with the gabbro.

There is but little, if any doubt, that the great physical break which separates the preceding from the following extends throughout the lake Superior district, and that it marks the greatest erosion-interval which has been discovered in paleozoic geology, as distinctly pointed out by Dr. A. C. Lawson.

A scant fauna has been found to characterize the terranes down to this point, and so far as the characters indicate, the fauna is primordial. This whole series, by its stratigraphic position, its fauna, lithology, and its accidental features, is bound in one grander group, and resembles that which is known as Taconic.

Nos. 3 and 4 are separable from No. 2 by divergence in dip and strike, as well as by a marked difference of lithology. Between these and No. 2 there is in Minnesota some evidence of nonconformity, and such has also been stated of them in Wisconsin.

5. Below this group is the fundamental "complex," made up of crystalline rocks and their debris. It is in this complex that are found some of the problems that have long been studied, and in which remain some of the unsettled questions. Still great advance has been made in deciphering its structure and stratigraphy. Three grand parts have been made out, in stratigraphic order, while a fourth is well established, but occurs sporadically. The first of these parts is a volcanic formation of great thickness, occupying, however a fixed position in geographic extent and in stratigraphic order. This is known as the Keewatin. Most of its rocks are volcanic tuffs presenting more or less evidence of aqueous sedimentation. There is one important part of this series, specially designated Kawishiwin, which differs from the rest. It embraces the great bulk of the "greenstones" and chloritic schists and jasperoid hematites of the formation, and it seems to be the latest known member of the Keewatin, although it still remains to be shown whether this massive greenstone phase be not of fitful distribution and liable to occur in other parts of the Keewatin. The most of the Keewatin rocks are graywackes, sericitic schists, agglomerates, conglomerates, with some exceedingly fine-grained, glossy, serpentinous schists. It also embraces modifications of these, which will be mentioned later. The conglomerates and the agglomerates appear at different horizons, the latter being especially abundant in the Kawishiwin horizon. The hematite ores which characterize the Keewatin, are found in the Kawishiwin stage. They are in lenticular lodes, and in general they stand upright, conformable with the general position of the rocks and and all the macro-structure of the country.

6. The next older rocks are conformably linked with the Keewatin rocks in stratigraphy, and they are no less intimately united with them lithologically. There is an increasing degree of fresher crystallization evident in the Keewatin toward the bottom, and when the strata become wholly crystalline they have received the name of Vermilion series. There has not yet been seen in Minnesota any unconformity between the Keewatin and the Vermilion, and indeed it appears that the crystalline characters occur sometimes out of their normal stratigraphic place, indicating that their existence is not dependent on stratigraphic order wholly—though in the main it is. The Vermilion schists, otherwise known as crystalline schists, contain magnetic iron ore, but generally they are destitute of it. They are usually plainly stratiform, in as evident a manner as the stratified rocks of the Keewatin, but they also embrace some dark, massive "greenstone" belts in which no stratification bands are visible. They consist essentially of mica schists and hornblende schists.

7. The base of the Vermilion, when not disturbed by upheaval in Archean time, has a gradual transition into conformable, stratiform gneiss, which is of like character with the transition from the Keewatin to the Vermilion. Indeed there is nothing to distinguish the Vermilion schists from the gneiss of the Laurentian, except an increase in the feldspathic and siliceous ingredients at greater depth in the series. Even after the Laurentian characters, viz., more or less massive or gneissic acid rock, have become fully established through a thickness of a hundred, or three hundred feet, there may recur, well within the gneiss, a parallel and extended belt of rock with struction and lithology like those of the Vermilion schists, or, *vice versa*, there have been seen thick beds of gray gneiss, conformable with the sedimentary stratification, well within the Vermilion schists, making an essential part of the series. Therefore it is plain that the base of the Vermilion, when not broken by upheaval and brecciation is an uncertain and vanishing plane which cannot be located exactly with any unanimity or consistency by different field geologists—nor even by the same geologist.

But this normal interstratification and gradual passage from the Vermilion to the Laurentian is not always found, nor indeed is it, perhaps, the most frequent. There is more frequently a great disturbance manifest at this horizon, resulting in brecciation and confusion. In most cases there are numerous "dikes" of the lighter-colored granitic rock cutting the schists, and there are larger areas and knobs ureless basic rock. There is every character that indicates that these were both in a fluid or plastic state, and that the only non-fluid rock was the older schist which is seen variously embraced in isolated pieces by both.

One other character pertaining to the structural relations of the parts of the Archean complex should be mentioned, viz: The eruptive characters just described, so far as they pertain to the Laurentian gneiss, do not always come into contact with the crystalline schists of the Vermilion, but sometimes small areas of Laurentian granite are directly in contact with schists that have the imperfectly crystalline condition of the Keewatin.

The Archean complex, therefore, is, normally, a unit in its grander features, and while separable into differing members, in the same manner as the overlying Taconic, and liable to disturbance and to the action of invading igneous rock, in the same manner it is plainly one in its grander history and its chief genetic characters.

With this statement, which gives a concensus* of the results reached by several geologists who have given special attention to the field evidences, we have given, perhaps, all that can be said to be settled as to the major structural relations. It is when we go further, and attempt to discover some of the minor relations subsisting between these parts, or enter upon the study of their genesis, that we find a divergence of opinion. These differences of opinion result, of course, from a study of the problems from different points of view, or along different ways of research, by reason of which different geologists have seen only portions of the evidence. It is to be presumed that when two geologists should see and comprehend all the facts there would be between them an exact agreement of opinion. The significance of a geological fact, when once pointed out, can be apprehended and applied only in one of two diverse directions, and can be used by one geologist as well as by another. This, of course, requires that the fact and its interpretation shall be embraced in a correct underlying philosophy. If a philosophical principle be assumed, at the outset, which is false, there will be danger of a vicious interpretation of all the facts that are discussed by the geologist who holds the false philosophy. He may be very expert in the discovery and the grouping of the relations of the facts which he employs, but all his reasoning is vitiated by the weakness, or worthlessness, of his initial datum. It is necessary, therefore, to examine every assumed principle on which this or the other interpretation is based, and to maintain among the facts discussed a rigid and correct rule of relationship within the accepted philosophy. It is equally certain that the correctness or falsity of a philosophical principle applicable to geologic facts, when pointed out, can be apprehended, and would be, by one candid geologist as readily as by another. There is hence, on the assumption that geologists are all candidly in pursuit of the truth only, a reason to expect that not only will all the facts necessary to the solution of present problems be discovered and known finally by all geologists concerned, but that they will be subordinated to a sound philosophical discussion and settlement.

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*The position of the principal gabbro horizon (that at Duluth and at Little Saganaga lake) may be excepted from this statement, as it is not settled so as to be admitted by all observers, that the gabbro followed immediately after the Pewabic quartzyte.

The unsettled problems pertaining to these rocks, whether in the Laurentian, the Ontarian or the Taconic, are very frequently connected with the "eruptive" members, whether truly eruptive or not, and with the genesis of some of the minor non-eruptive parts. It might be mentioned also that there is still some question as to the stratigraphic place of the gabbro of the Mesabi range of hills and as to its relation to the Animikie. There is also some uncertainty as to the manner of distribution of the eruptive rocks both of the Animikie and of the Nipigon through those formations, and the effect of such distribution on the cotemporary sedimentary beds at places remote from the points of issue of the eruptives. In short, it is not altogether certain but that the terms Nipigon and Animikie have been applied to some extent at different and distant points to different but cotemporary phases of the same formation.* The Pewabic quartzyte shares less in this uncertainty, maintaining its identity at the base of the Taconic.

## USE OF TERMS.

It is one of the primary essentials to the investigation of the crystalline rocks, after the ascertainment of their physical and stratigraphic characters, that there shall be a clear understanding of the terms selected to define them, and this necessity appears greater in no case than in the use of the terms "metamorphism," and "alteration" and the terms "schistose," "laminated," "stratified," "gneissic," "bedded" and "banded." These terms have been variously employed, and great confusion has resulted.

Anyone who has given attention to the rocks as they appear in the field will have noted that there are two opposing tendencies of change which the Archean rocks have experienced. He finds a force, or several forces, which promote what might be styled a destructive or degradational transition from one mineral condition to another—in other words a *weathering process.* This has resulted both in past geologic eons and in the short time that has elapsed since the glacial epoch, in converting hornblende to chlorite and to talc or serpentine, biotite to muscovite, and to the various hydrated micas,feldspar to mica or kaolin, menaccanite to leucoxene, and in short, it is that change which is preliminary to the final disintegration of the minerals concerned and their disappearance either in the superficial soils or in solution and distribution in any waters that can carry them away. The forces that promote this change are water and atmospheric air, and since these have been present since the rocks existed as rocks, and were also present and equally or more active at the date of their birth, it is plain that the effect of their influence will be likely to be found throughout the history of the Archean rocks, at all points where there can be said to be any identifiable data to mark their history. It will be noticed that all these changes of condition result from an attack, an ever energetic assault, which the atmosphere, through some of its agents, is making on the primary elementary conditions of the minerals of the earth. It is essentially a carbonizing, an oxygenizing and a hydrating process.* It is ever present, and its avenues of effective attack are myriad. As a result of this warfare between the earth and the air the surface of the earth has become habitable by the various grades of organized beings, vegetable and animal. This process is one of the most important, in its progressive steps, and one of the most stupendous in its results, however slow and gentle it appears, which we can contemplate in the history of the earth. It is not designed here to dwell upon it, although it has resulted in the production of all our limestones, sandstones, shales and usual soil-producing strata, and has brought about those conditions by which water at ordinary temperatures can remain permanently on the surface of the earth.

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* The Nipigon here is supposed to be the equivalent of the Keweenawan, to which this statement more strictly applies.

Opposed to this destructive process, the geologist who contemplates the crystalline rocks observes another operation. This force acts to expel the carbon and the water, and as much of the oxygen as possible, which have been taken up by the operation of the destructive process. This is essentially a reconstructive operation, and its effect is to bring all the minerals subjected to its action back again to or toward the conditions which they possessed originally. The reconstructive process will be impeded, naturally, and sometimes diverted from its normal result, by accidents of environment, either physical or chemical, which have transpired since the primary crystallization, through the action of the destructive agents of the air, already mentioned. For instance, whereas a normal and natural change, through destructive agencies, would be manifested in the conversion of augite to hornblende, and of hornblende to chlorite, and also of an orthoclase feldspar to a potash mica, and thence to sericite, and to kaolin, when the reconstructive process were to take these final products in hand, it would not be able, perhaps, to restore them to their original conditions of composition and crystallization, producing augite and orthoclase feldspar, but the utmost of its results might be a form of hornblende and a black mica. Certain natural and insurmountable obstacles seem to oppose the reformation of exactly the same minerals through that method of regeneration. It cannot be questioned, however, that could the original conditions be restored, both of heat, pressure and moisture, and the same forces be brought to bear on the same elements, in the same proportions, as in the first crystallzation, the result would be the reconstruction of identically the same crystals. This recrystallizing process, compared with that of disintegration, is much less observable, and in the later geological ages it is less common than in the earlier. This apparent diminution, however, may be only apparent, and due to the fact that its later effects are likely to be buried at great depths below the clastic strata of the supercrust, and hence invisible to the geologist. It is only where and when some of the causes that promote it break through the supercrust and become apparent at the surface of the earth, as in the cases of volcanic forces, that the student of these rocks can observe the method of this reconstruction in the production of its characteristic minerals. The causes that produce these retro-changes are, hence, only exceptional and local, and do not disturb in the grand aggregate, the onward course of the unequal warfare between the air and the earth, which inevitably is tending to the subjugation of the latter by the former. The reaction of the crystalline forces against disintegration was most powerful and effective in Archean time, when the earth was heated nearer the surface. The voluminous sedimentation that resulted from the first attacks of the atmospheric agents on the heated earth's surface, has been the most exposed to this re-construction. At that early date in the formation and dissemination of fragmental materials by the air or the ocean, the nature of the sediments themselves had not so far become differentiated from their parent sources, as are the sediments of the present ocean, and in the event of re-construction could more easily and more abundantly re-produce the minerals of the parent rock. The forces which are concerned in the reconstruction of the primary minerals in the Archean rocks, are seated below the crust of the earth, and their power seems to increase at greater depths. Whenever they manifest themselves in concrete form at or near the surface they are combined, in some occult relations with pressure and moisture. Primarily we may, perhaps as correctly as any way, express these forces in a single term, by the words *dry heat*, either as the result or as the cause of gravitation, but as dry heat was associated with varying degrees of pressure and perhaps of moisture, in the first crystallizations, so it appears to be, even more closely, associated with the same agents in the production of the restored re-crystallizations. Hence it would be equally correct, for our present purpose, to ascribe all the reconstructions of which we are speaking, to the three well known agents of metamorphism, viz., *heat*, *pressure* and *moisture*. When these combine in their action on any of the early sediments, such as may have been long subjected to levigation and hence may have been greatly changed from their parent condition by the ocean, the concentrated effect is to cause the greatest degree of re-crystallization, and restoration of primary characters.

These two opposing processes produce characteristic mineral species, and in their multiform physical reactions upon each other, under constantly varying physical relations, and varying chemical surroundings, they give rise to a large number of intermediate and unstable mineral species, which are characteristic of neither one nor the other. Such are the zeolites, the sulphides, some carbonates, etc. But the principal characteristic minerals which each process gives rise to, are too familiar to need enumeration here.*

Now, as both these processes result in a change of mineral condition in the rocks, the resultant rocks may be said to be metamorphosed. Indeed, the term "metamorphic" has been applied to each. Those who are predisposed to consider all rocks sedimentary until they can be proven to be of eruptive origin, have been prone to apply the term "metamorphic" to not only those banded schists (the mica schists) which preserve a plain sedimentary structure, but also to those greenstone schists which do not preserve evident sedimentary banding, but whose minerals are fragmentary and plainly in a state of transition from a once more perfectly crystalline condition to a state of greater disintegration.

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*The chemical potentialities of silicon being called out mainly at high temperatures, and those of carbon at more moderate temperatures, they seem to stand, as it were, at the two opposite poles of matter, dividing the empire between them into what we commonly call the Organic and the Inorganic, but with very undefined boundaries along which dwell a series of restless and turbulent tribes, the individuals of which own no permanent allegiance to either, passing from the domain of each into the other in the most facile manner.

On the other hand, those who have been prone to claim every crystalline rock as eruptive until it can be proven to be of sedimentary origin, have been equally liable to ignore the necessary great divergence between these two operations, and to set down as eruptive not only those massive crystallines which are plainly eruptive, but, also those imperfectly crystalline masses, whose grains are in a transitional state, like the schistose greenstones, attributing their semi-disintegration to a force or a process known as "dynamic metamorphism."

For the present purpose we shall apply the term *metamorphism* only to the reconstructed rocks whose minerals have been forced to take on a condition of more thorough crystallization by the application of the forces of heat and pressure in the presence of moisture. The micaceous and hornblendic schists, the Vermilion series, as above described, illustrate this metamorphism. The gneisses into which the Vermillion schists pass conformably, downward, also illustrate it perfectly. All other rocks whose minerals are changed by weathering, from the crystalline condition in which they were when the rocks were formed, may be styled *altered rocks.* Here, however, there is danger of assuming a condition to have prevailed in a large class of rocks that have been much studied, which the facts will not prove to have been their condition. I refer to the greenstones and the green schists, as a group, although there are plainly unimportant portions of these green rocks which should be excepted.

Again, there is a tendency among those who have been familiar with the structures of sedimentary rocks, on the one hand, to carry their ideas of sedimentary structure too far, and to make all the "parallel structures" which they see pervading the crystalline rocks, so many modified forms of sedimentary structure; and on the other hand a class of geologists who have become familiar specially with the structures that crystalline rocks may be made to assume under pressure and partial fracture causing the schistose arrangement of the entire mass, have been inclined to subordinate to mechanical causes acting subsequent to solidification, all those "parallel structures" which they may discover in a crystalline rock, however plainly they may have originated from sedimentation. To one class of observers, however many mistakes they may fall into in interpreting all these structures as due to sedimentation, the terms banding, lamination, schistose, gneissic, sedimentary structure, cleavage, &c., all mean fundamentally the same thing, and with great confidence sometimes they make out a "synclinal" structure for a great area, and have no more basis for it than a superficial synclinal arrangement of the slaty cleavage. To the other class of observers, however great the apparent absurdities into which they may fall, these structures signify equally but one thing. They extend an observed result, viz., schistose or slaty cleavage, a product of pressure and shearing in a rock mass, not only so as to destroy its true, normal significance, but also so as to include structures that are known to be produced only by sedimentary forces—they attribute to pressure and dynamic metamorphism all the banding and stratification which some crystalline rocks so plainly manifest. These terms, therefore, about the significance and applicability of which so much has been written, have come to be the weapons which either party may use with perfect success, so long as they have no definite meaning. It is plain that, in order that either one or the other party shall finally prevail the distinctions which should mark these terms when correctly applied, must be ignored, and as far as possible broken down. The plutonist is inclined to ignore all the evidences of sedimentary structure in these questionable rocks, knowing that he has a firm starting point in his argument, and he ruthlessly drives the extreme of his argument into conflict with a set of important facts and structures coming from another direction. The neptunist, starting from an equally firm datum, with his eye only on one result, following his bent with equal rashness, finds himself soon beset with such problems and snares that he wantonly assails or denies evidence which is as valid as that which formed his point of departure. There must be certainly some middle ground. There must be some significance for these terms which, when carefully adhered to, will prevent one truth from apparently clashing against another. To adjust these differences by a consistent use of these terms, seems to be the most reasonable first step. It cannot be denied that there is such a thing as sedimentary bedding and banding, but this should be followed only so far as it can be distinguished as such, leaving all beyond to some other possible explanation. There is also with equal certainty, such a thing as a "diabasic structure," *i. e.* a structure resulting from crystallization from a molten magma, and so far as it can be followed, without essential modification, it ought to be allowed its full force. When its typical characters fade out, and the rock may possibly be ascribed to a different cause, it is unfair forcing of the evidence to insist that the "diabasic structure," feebly discernible, shall interpret the whole rock mass if the mass exhibits any other adverse structures.

In the field it is very easy to distinguish a true sedimentary banding(1)* from all those other structures into which it has been supposed to graduate, and with which it has been confounded. On the weathered surface it is indicated by varying shades in the color-bands that cross the surface, and on close examination it will be found to exhibit, in the different bands, or beds, which may be of any thickness from a sixteenth of an inch to several inches or several feet, not only a difference in the sizes of the constituent grains, but generally a difference in the relative abundance of the same. Usually free quartz grains will be found more common in some of the bands than in others, giving rise to lighter colored and harder layers. It so happens that very frequently the upheaving forces which have caused the strata to exhibit their truncated edges, have at the same time subjected them to such pressure, in a parallel direction, that the same rocks exhibit a finer slaty cleavage parallel with this sedimentary structure, and as the process of weathering brings out the slaty cleavage conspicuously, while the original bedding may become obscure, in case the cleavage direction gradually becomes discordant with the bedding the observer is liable to follow the cleavage in his measurements of dip and strike, under the impression that the two structures are essentially concordant. This structure which is due to sedimentation has another characteristic, viz: The coarseness observable in any chosen layer of the rockmass will be found to change gradually to one of considerable fineness, (and *vice versa*) in crossing the structure perpendicularly. There may be abrupt transitions from coarse to fine, or from light to dark, but these are not so sure evidences of sedimentary action as those gentler transitions which sedimentary materials take on under the gently changing force of currents. These color-bands will be found to maintain their courses independent of all other structures, and when they are not parallel with the schistose structure or with the slaty cleavage, the schistic structure and the cleavage will be seen to take on varying characters from layer to layer, as they cross the sedimentary beds. In general, the slaty cleavage (as well as the schistose structure) ceases, or becomes less and less evident, on entering the coarser beds. Indeed it appears to be a general principle that slaty cleavage only occurs in clastic beds of very fine grain. Clastic beds that have great uniformity, through great thicknesses, both in composition and in fineness of grain, when subjected to great pressure in two or more directions, and especially if a shearing movement be produced in the mass, take on a schistose structure (2). This consists in an initial production of slaty cleavage in two or more directions, cutting the rock into rhomboidal masses of greater or less fineness. These rhombs may then be more and more elongated in a uniform direction, all the constituent grains suffering a slight disturbance and sometimes fracturing *in situ*, some of the finer grains or fragments streaming out into tails in the lea of the coarser grains. When the stretching is extreme there is apparent a pseudo-streamed structure, and even a close pseudo-basaltic jointage, which gives the apparently once plastic mass a great resemblance to true irruptive (plutonic) rock. This dynamic action results at first, of course, only in a partial destruction of the integrity of the rock, and of its embraced mineral grains, and so far as it ceases before sufficient heat is produced or concentrated to reconstruct the minerals, it is entirely a degradational process, and fits the rocks so affected, better for the destructive action of the elements. A very great difference is observable in those cases in which the shearing movements were sufficiently intense to cause fusion, or to cause a reconstruction in part or in whole, of the minerals of the rock. (3) This, however, is a phase of the subject which will have to be considered separately. I desire here only to call attention to one important fact, which distinguishes the schistose structure, and slaty cleavage, wherever produced in massive rocks, from the sedimentary structure already described, viz: There is no transference of the constituent grains *across the structure*, and no selection of the coarser or of the more siliceous portions and the arrangement of them in separate and continuous bands or sheets that show any parallelism like that of sedimentation. Indeed when the two structures are seen to cross each other, they are always very different, and they are invariably contrasted in this particular. As these three structures—or more correctly these two, since schistosity is an extreme and confused development of cleavage—have so widely different origins, and can be distinguished by so obvious a character, no competent observer ought to confound them, and in the choice of terms he ought always to restrict each to its proper object.

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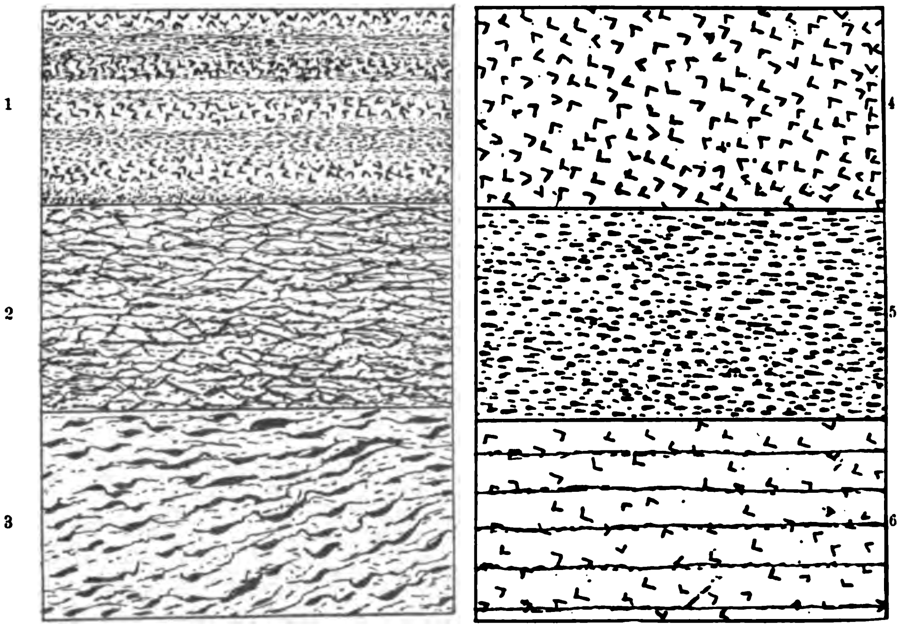
*No. 1, of the figure on page 16.

These two structures are both found in nearly all the crystalline terranes, the only exceptions being those rocks which are plainly the result of cooling from fusion (4), which constitute only a subordinate part. The schistose structure, in some form, pervades all the Archean complex, including also the irruptive rocks, although it is plain that its origin in the irruptive rocks which have invaded the fragmental, is of later date and its development necessarily less perfect, than in the fragmentals themselves. It here takes on the form, sometimes, which is more frequently denominated gneissic, as it is found in some of the crystalline massives. Reference is not made here to a true intersheeted, sedimentary structure(1), such as characterizes the mica hornblendic schists and the gneisses into which they gradually pass—sedimentary rocks re-crystallized *in situ*—but to a homogeneous, or nearly homogeneous, acid rock, evidently the result of crystallization from a molten or plastic condition, classed as granite or syenite ordinarily, or as simply gneiss, in which there is a roughly parallel structure in the mass, caused by the elongation of the mineral crystals all in the same direction(5). This is a very feeble "schistose" structure, and ought to be separated from the term entirely, as it is due apparently to another cause, viz.: a slight fluxion in the mass while the crystals were forming. Again, the granites carry this "gneissic" structure to a still greater development, and it is apparently some form of the same which is seen in a kind of foliation (6) by which they are separable into irregular layers or sheets from an inch to three or four inches thick. This foliation differs from the gneissic structure already described, in having a bedded rifting, which becomes conspicuous on weathering and which embraces large areas in a common strike and dip—while at the same time the layering is not attributable to sedimentation, of which it does not show the characteristic color-bands, and the peculiar intergradations of coarseness and fineness. This higher development of the gneissic structure may be attributed at present to successive applications of heat at different temperatures or to fluidal flowage while the mass was molten or plastic, although it has been taken very largely to be the remains of an original sedimentary structure. Its cause is still problematic.

In respect to the diabasic or ophitic structure in basic eruptive rocks, when it is well exhibited there are perfectly formed, lath-shaped plagioclase crystals disseminated among the imperfectly formed other crystals of the ground mass. This structure rarely appears in the granitoid acid rocks. When it does, porphyritic crystals of orthoclase with idiomorphic outlines, are surrounded either by a micro-pegmatite of quartz and feldspar or by a finer crystallization of all the regular minerals that constitute the rock. In either class of rocks this structure is considered one of the surest evidences of the igneous origin of the rock. The amygdaloidal structure, which is produced by superficial cooling, is also one of the original characters of igneous rocks, although there is produced in sedimentary strata[*] sometimes, when intensely affected by heat and pressure, but not reaching fusion, a spottedness, and even a partial vesicularization in which certain minerals are segregated, which strongly resembles the true amydaloidal structure of igneous rocks.

If the foregoing principles be applied to the various forms of structure, and the terms as defined above be employed to express them, there might be constructed a tabulated embodiment of this terminology which would take the form seen on p. 17. In this table the usual characters due to weathering and final disintegration, and to kaolinization, are not included. The table is designed only to express those structures, both original and secondary, which the Archean sedimentary and igneous rocks are found to assume in the field, and to ascribe to each structure its cause, and some of its relations to other structures.

FIG. 1. STRUCTURE OF CRYSTALLINES ROCKS.



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[*] Parker Cleaveland stated in 1822 that the amygdaloidal structure is sometimes seen in bedded and clayey rocks, or "indurated ferruginous clay." "An elementary treatise on mineralogy and geology."—Vol. ii, p. 753.

## TABLE OF ORIGINAL AND ACQUIRED ROCK STRUCTURES.

| | | CAUSES. | REMARKS. |
|---|---|---|---|
| SEDIMENTARY ROCKS. | *Stratification.* | | |
| Original. | ( 1) Color-banding and graduations in kind and size of grain across the bands. | Sedimentation. | When the grains are not of quartz they are blurred by decay. Crystal outlines not perfect. |
| Acquired. | ( 2) *Slaty-cleavage:* The grains flattened in the same direction. | Pressure in one direction. | This is usually simple compression. |
| | ( 3) *Schistosity.* The grains elongated in the same direction. | Pressure in two or more directions. | May be accompanied by shearing. No. 2, of fig. 1. |
| | ( 4) *Bedded Gneiss.* Reconstructed crystalization, *in situ.* | Deep-seated hydrothermal agents. | When fused this rock becomes igneous (acid) No. 1, of fig. 1. |
| | ( 5) *Fusion* and displacement; crystallization. *Augen-gneiss.* | Heat and shearing pressure. | This is strictly then an igneous rock. No. 3, of fig. 1. |
| IGNEOUS ROCKS. | ( 6) *Granitic.* Homogeneously massive. | Normal and uniform cooling. | Applicable to both basic and acid rocks. No. 4, of fig. 1. |
| Original. | ( 7) *Porphyritic.* (Acid and basic rocks) | Two consolidations. | Earlier crystals idiomorphic. In acid rocks, quartz and orthoclase. |
| | ( 8) *Ophitic.* (Basic rocks.) | Two consolidations. | Plagioclase crystals idiomorphic. |
| | ( 9) *Amygdaloidal.* | Rapid cooling; generally at the surface. | Later formation of zeolites, calcite, etc. |
| | (10) *Gneissic.* Uniform elongation of the mineral grains. | Fluxion at time of consolidation. | The rock remains massive—*i. e.* not foliated. Massive gneiss. No. 5, of fig. 1. |
| Acquired. | (11) *Schistosity.* | Shearing pressure. | Perhaps caused also by multiple cleavage. No. 2, of fig. 1. |
| | (12) *Foliation.* Regular parting-planes in massive rocks; slight formation of mica along the partings. | Cause uncertain. | Perhaps alterations of heat at different degrees. Foliated gneiss. Jointage is not here included. No. 6, of fig. 1. |
| | (13) *Foliation and Augen-gneiss.* | Shearing after consolidation. | Sedimentary "foliation" is not here included. Foliated gneiss. No. 3, of fig. 1. |
| METAMORPHIC ROCKS. Acquired Characters. | Reconstructed crystallization *in situ*; may show any of the acquired characters of sedimentary and some of those of igneous rocks. | | |

In what follows we shall employ these terms as here defined. We must insist on the actuality and the validity of both of these characteristic structures as they appear in their original rocks, *i. e.* on a sedimentary structure and on an igneous structure, because it is impossible to deny the existence of either, and wherever these contradictory structures appear to exist cotemporaneously in the same rock-mass, we shall try to find some means of reconciling the contradiction, or to show that the supposed existence of both is due to either an incorrect initial underlying philosophy, or to mistaken observation.

## COMPARATIVE VALUE OF MICROSCOPIC AND FIELD EVIDENCE.

There is an essential difference between the evidence derivable from the microscope and that which comes from the study of the rocks in the field. At first glance it would seem that there could be no misunderstanding of the nature and relations of this different evidence, but here is where one of the fundamental errors has been committed. It is in the nature of the problem involved in the study of the complicated structures and relations of some of the Archean rocks, that the difference between the microscopic evidence and that derived from their macro-structure shall gradually fade out, and that one or the other shall usurp the whole field. This has already been alluded to. It is plain, therefore, that the two investigators, one following microscopic and the other field evidence, on a certain line of observation, would certainly reach a point, where, in respect to a certain structure, or a certain rock-mass, they would be at point-blank disagreement. That is, to the question: *Is this a sedimentary rock?* One would answer *yes*, and the other would answer *no*. It is in such a case as this that there is need of examining into the underlying principles through which these different results may have been reached.

It should be observed, at the outset, that the microscope takes cognizance of the intimate structure of the rock. Of itself it cannot observe the macro-structure, nor know anything about it. It cannot of itself take note of stratification nor of schistosity nor foliation. These are objects for the student of field relations, *i. e.*, as to their existence or non-existence. On the other hand, the field observer, of equal capacity and veracity, takes no notice of the intimate structure—or only so far as the unaided eye can detect it—and derives his conclusions from characters which are obvious. In each line of observation, the experienced observer, or the specialist in the microscopic phenomena studied, should be allowed to have his own way. His determination of the questions arising within the normal sphere of his observation should be allowed to stand. It is only when one or the other transgresses the limits of his specialty that his conclusions may be questioned in case of conflict. If the field-observer extends his theories of sedimentary structures, either original or modified, beyond the limits of actual observation, in contravention of the conclusions of the microscopist, his theories must give way to those of the microscopist. If the microscopist extend his theories beyond the limits of his domain, and attempts to draw conclusions as to megascopic characters, or physical structure, in contravention of the determinations of the field-geologist, he is equally outside of his legitimate sphere, and his results cannot stand against those of the field-observer. This is not intended to shut out any individual geologist from exercising the right to employ any and all lines of research for the solution of all the problems that he has to solve. It is only intended to call attention to the different spheres and qualities of the different kinds of evidence, whether these kinds and spheres be in the hands of different geologists, or both in the hands of the same geologist. Indeed it is the individual geologist, generally, who handles both these sorts of evidence, who is driven to weigh them carefully and to separate between them when they collide. It is for the satisfaction of the individual geologist that this contradictory testimony must be examined into, and each given its legitimate weight.

Now the existence of a sedimentary structure in a rock is one of those outward, megascopic characters which the field-geologist only can be allowed to pronounce upon with authority. The structure itself in any normal case is so evident that none will doubt its existence—the doubt that arises in any special case is that of its genesis, and hence whether the case in hand be a true sedimentary structure. The field-geologist can perchance trace the structure back by degrees to rocks that show it in unquestionable perfection. He cannot deny the testimony of his senses. The microscopist, on the other hand, may have followed his minute characters with equal assurance till they have been traced into this banded rock and he now affirms that this is not a true sedimentary structure, but is one produced on originally irruptive rock by secondary causes, such as pressure, shearing or brecciation in parallel lines, followed by substitution of greater amounts of quartz along the planes of brecciation. That there are cases of such contrariety of opinion there is no question among the geologists who have worked among the crystalline rocks. We presume here a case in which the observers are both competent and reliable, and whose veracity and judgment no one would willingly call in question. It is evident, however, that one or the other is wrong. It is the desideratum here to determine which is correct. It would seem to be a fair adjustment, other things being equal, to allow each observer in his own special field to have his own way. It is pertinent then to inquire whether the field-geologist or the microscopist is here trespassing beyond the limits of his legitimate field, and usurping functions that do not belong to him. The grand structures of a rock-mass are observable and comprehensible by all observers, and they cannot be misnamed, nor can their significance be reversed by anyone. They cover and precede all minuter inspection by the microscope. They cannot be denied by the microscope. If the microscopist by a laborious course of observation and speculation reaches a conclusion that contravenes the conclusions correctly based upon the grand rock structures, the microscopic conclusions must give way or must be amended so as to agree with the truth, which is evident to everyone or which is the result of study of patent facts correctly interpreted. In the same manner sometimes the paleontologist exalts his results above those of the student of physical structure and denies some of the most obvious truths of geological succession. He forgets that paleontology is nothing unless it be preceded by stratigraphy, and that unless there be a predetermined order of succession in rock masses, his paleontological results could not be arranged as historical data. In the same manner that stratigraphy involves and governs paleontological reasoning, so does the macro-physical structure of crystalline rocks govern and involve the study of their microstructure.

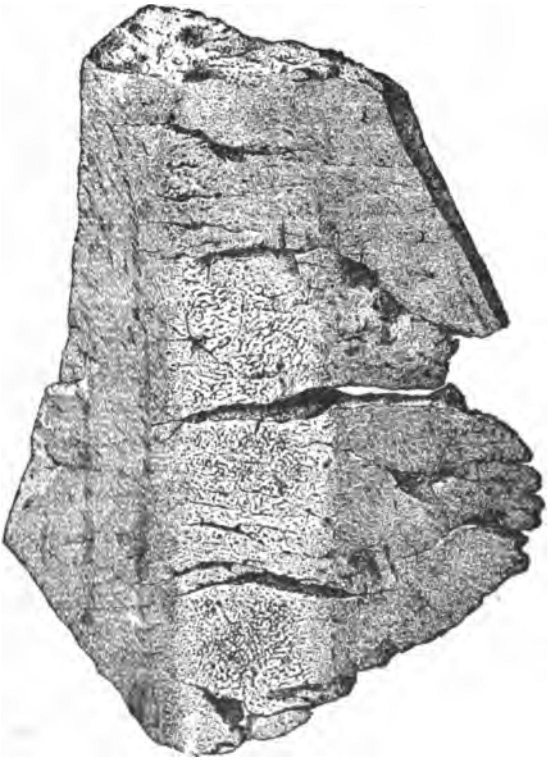
Now let us take a concrete case. Unfortunately the differences which formerly separated the plutonist from the neptunist have not been reduced materially by concession and by demonstration of error, on one side or the other, to any limited group of rocks. Therefore we may take our concrete example from the so-called greenstones, which is a class which exists in nearly all parts of the world where the Archean rocks prevail. We will choose a rock which manifests one of the structures whose origin is in dispute between the microscopist and the physicist, viz:

### 1. ACCORDING TO THE MICROSCOPIST.

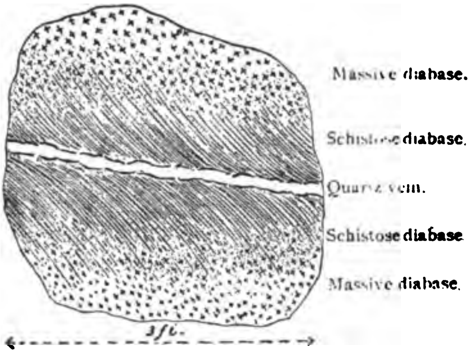
A rock alternately schistose and massive; the schistose sheets being much more broken and decayed, in their granular structure, than the massive sheets, and having a distinct parallelism in the direction of the constituent grains, with the ophitic structure completely lost; the massive sheets being of more perfect and evident crystalline integrity, and having the schistose arrangement seen in the granular condition of the schistose sheets only faintly observable, while there is preserved, with more or less distinctness, an occasional trace of the ophitic structure. These features, as they alternate, produce on the surface of the rock a parallel banding resembling stratification bands.

### 2. ACCORDING TO THE FIELD-OBSERVER.

A stratified greenstone, alternately striped by bands of lighter and darker green. The schistose character, which sometimes is rather a slaty cleavage, is more evident in the finer beds than in the coarser ones, or wholly disappears in the latter. It does not agree in direction with the course of the stratification bands, but crosses them at an acute angle which angle vanishes as the finer beds grade into the coarser, also changing a little in direction so



as to approach nearer perpendicularity to the grand bedding—showing apparently a shearing pressure to have been its cause.



The structures here referred to are illustrated by the above figures, which are taken from bulletin No. 62, of the U. S. Geol. survey (Williams), where they are referred to dynamic metamorphism and are said to be in no way dependent on sedimentation. These figures could be repeated many times in the course of a brief examination in the field. These cases present the issues fairly. It remains to be decided whether the testimony of the student who relies on his microscope, and starts out with the idea of subordinating his facts to the answers it may give, or that of the field-observer, who only studies the grander structures and has a predisposition to explain such as the foregoing by referring them to sedimentation, shall here be received with the greater credence.

## THE PHILOSOPHY OF DYNAMIC METAMORPHISM.

It has been stated already that the term metamorphism is applicable to these rocks whose constituent grains have been reconstructed by a second crystallization by the action of heat, pressure and moisture, a process the reverse of weathering, by which mineral grains undergo a degradational change. But the term "dynamic metamorphism" has been applied extensively to a set of changes that do not fall within the meaning of metamorphism as thus defined. It has been employed to explain the structures seen in the greenstones, such as schistosity, color-banding, foliation, and also all those minute imperfections in form, and the chemical transitions that the minerals of the greenstones exhibit. Hornblende wholly or partly converted to chlorite, is a degradational change. Saussuritization, a decay in a plagioclose feldspar, is a degradational change. Augite converted to hornblende is a step toward ultimate disintegration and decay; ilmenite changed to leucoxene, or to sphene, is on the road to decomposition and loss. Orthoclose kaolinized is ready to disappear on the approach of the feeblest physical disturbance. These alterations, all of which in other rock-masses are attributable without question by any one to weathering and destructive agents, are assigned, as stated by some microscopists, to "dynamic metamorphism," which therefore would be a metamorphism in the opposite direction from that which is usually understood by the term. There is no inherent valid objection to the use of the term in this sense, so long as it is clearly understood what kind of a change is meant by it. The most important point to be considered in the application of the term, is whether the assumed cause, if it should be found to have operated, could produce the effects which are seen, and whether it is the only cause which could produce those effects. The forces of dynamic metamorphism as defined and applied are wholly mechanical and then chemical. Heat and moisture are not included. Shearing pressure, direct pressure, stretching and fracture are all appealed to.

There seems, however, to be an *a priori* inconsistency in supposing that mechanical force can be applied in sufficient intensity to crush or partly crush a rock-mass and yet not to produce a perceptible degree of heat. And there is much room to doubt the possibility of such crushing in any natural rock-mass within the super crust, without the presence of moisture. While it is apparent on every hand that great deformations have taken place under the action of mechanical forces, producing upheaval, stretching, faulting, brecciation, cleavage and schistosity, it is equally apparent that where these changes have taken place in their greatest intensity the rocks have been fused and recrystallized; many examples could be given. Hence it is evident that where these forces have acted to produce less mechanical deformation, there was a smaller amount of developed heat, but not an absence of it. If mechanical force be applied therefore to a rock-mass, with shearing friction so as to disturb the grains in respect to each other or to crush some of them, the inevitable effect of the heat which is generated thereby is not a degradational one, but a reconstructive one, and, aside from the more easy weathering that might be a consequence when such rocks were exposed locally to the action of the elements, the crystal grains would be strengthened in their chemical bonds, and perhaps built out afresh in their natural contours. If a degradational change be generally observed throughout the interior of such rocks, it is unreasonable to attribute it to mechanical force *per se* operating to break the grains. It must be explained by appealing to some other cause.

Again, the philosophy of dynamic metamorphism, if not at fault fundamentally, must explain a singular anomaly. The greenstones as a body everywhere are younger than the crystalline schists as a body, but they grade into each other imperceptibly, passing through the intermediate stages of sericitic schists and graywackes. The greenstones and their appendages, the chloritic schists, must have shared in no mechanical transformations to which the underlying crystalline schists were a stranger. It would be a physical impossibility to subject the overlying schists as a body to dynamic metamorphism, (pressure, shearing and crushing) without including the lower schists, and if the forces of dynamic metamorphism be accountable for the semi-decayed condition of the "greenstones," why was not that change wrought also in the crystalline schists? On the contrary the crystalline schists, normally, are fully and perfectly crystalline still—as perfectly crystalline as any granite or gneiss, only differing from the great mass of the Archean gneiss in physical structure, or in the relative amounts of the contained minerals.

## THE ANOMALOUS CHARACTERS OF THE GREENSTONES AND THE GREEN SCHISTS.

No thoughtful student of the crystalline rocks can fail to note, as long since claimed by T. Sterry Hunt, an order of succession in the relative abundance of certain minerals that constitute the Archean rock-masses. He hence also notes an order of succession of kinds of rocks. In Minnesota this order has been found to be the same as that worked out in Saxony, Italy, western France, Scandinavia and Great Britain. The same succession has been published by Lawson for the crystalline rocks of Manitoba. In each case there is a body of greenstones, associated with chloritic and sericitic schists, which forms the summit of the Archean terrances. In other words, it has been found that there is, first, a great series of acidic crystalline granites and gneisses at the bottom, these sometimes exhibiting unmistakable evidence of fusion and displacement among later bedded schists, and hence locally overlying the schists. These thoroughly crystalline rocks are followed by a series of equally crystalline schists which contain much mica and hornblende, and vary from acidic to basic. In the upper portions of these, which are here distinctively called "crystalline schists," there is an increasing amount of non-crystalline, or semi-crystalline, matters, and here the detritus has been found to consist very largely of unmistakable volcanic tuffs, intermingled minutely with chemically precipitated silica. Somewhat higher, but connected by a series of conformable gradations, both stratigraphic and petrographic, are the greenstones and chloritic schists. So far as known these constitute the highest portion of the pre-Taconic complex. As a grand division of the Archean they approach nearest of all the Archean rocks in their mineralogic characters, as well as in their physical structures, to the well-known characters of basic eruptives. It is a remarkable fact that the first detrital depositions of the Taconic sea, which lie unconformable above these greenstones and chloritic schists, and which extend further back and also overlap in the same manner the crystalline schists and the older gneisses, are highly acidic normally, although affected locally by debris referable directly to the rock underlying or to volcanic tuffs. It appears, therefore, that the greenstones are interposed with their anomalous mineral characters, chronologically between two epochs whose rock-formations were dominated by more acidic characters. It appears also that on the lower side there is a gradual transition from the oldest acidic into this highly basic, but that on the upper side the transition is abrupt from the highly basic to the highly acidic accompanied by a widespread, pronounced unconformity of stratigraphy. It is this general semblance of the greenstones, as a body, and the identity of some portions of them actually, with well-known characters of eruptive diabases, which furnishes the most evident and powerful argument for their derivation from true irruptives through a series of long-continued so-called "dynamic" changes, and which is the chief obstacle to the neptunist in his attempt to assign them to an aqueous origin.

There is a great significance in this anomalous mineralogical character of the Kawishiwin phase of the Keewatin, and in the nature of the transitions to it from above and below. In general it points to a gradually increasing force in that agent, whatever it was, which gave origin to the "greenstone" element of the Keewatin, and to a rather sudden culmination and cessation. It further points to such a shrinkage of the bulk of the earth's land surface, compared with that of the water area, that the ocean's waters prevailed over large areas which had before been dry.

## THE NATURE OF THE CAUSES WHICH GAVE ORIGIN TO THE CRYSTALLINE ROCKS.

It has been customary to speak of the crystalline rocks as a unit, and to refer their existence to the operation of a single force. In a broad sense it may be legitimate to refer them to one cause--the refrigeration of the earth—or to the action of gravitation in its specializations—but as geologists we are bound to inquire more closely. So long as we knew of no widespread, or even local, serial succession in these rocks we could but speculate on them as a whole. But since now they may be differentiated into groups having marked distinguishing characteristics, it is incumbent on us to find a cause for each group. In has been one of the striking facts in the history of geology that geologists have specialized more and more, in their observations, and have been compelled to separate their generalizations into several parts, applying only a part of their former ideas to some special phenomena, and being compelled to recognize new principles in order to explain the rest. There is, however, one great feature which binds the Archean rocks into one great group, and which indicates that they have shared in one sense in a common history. They have been upheaved and pressed together in sharp folds so that now they present everywhere in Minnesota (and the same is true of the whole Northwest and for Canada) their truncated edges vertically, or nearly vertically, to the observer. After this upheaval and truncation they were submerged beneath the Taconic ocean—at least the Taconic strata now lie, in attitude sometimes horizontal, unconformable upon them, presenting one of the most notable and widespread instances of unconformity of stratigraphy,and one of the most remarkable changes in lithological characters. In the sense then of constituting a "floor" on which the admittedly clastic strata repose, those rocks may be classed as a unit, and may be said to occupy a single period in the earth's geognosy entirely unique and separate from all the other periods. Yet when we look at the series by itself we soon see that there is no other equal amount of rock-material in the purview of the science of geology which presents so numerous and so great contrasts of composition, and yet which presents a greater persistence in the orderly succession of its main parts. We are forced therefore to note, as the *first* element in the nature of the forces that evolved the crystalline rocks, that they were not local in their extent, but were apparently world-wide, and as such succeeded each other in their operation.

*Secondly*. Although there is a profound stratigraphic break between the Taconic and the uppermost member of the "Archean floor," yet it is plain, by the existence within the Taconic of rocks of the same nature as those of the "greenstone" stage of the Keewatin, that the close of the Archean did not witness the suppression of the characteristic forces of the Keewatin. Those forces (plainly

# II.

# FIELD NOTES OF N. H. WINCHELL.

## IN 1890.

*Northern Pacific Junction. Slate quarries of Dietz and Dugan*; about three miles north of N. P. Junction, Oct. 16. Calcareous but soft, rusty lumps appear here in the same manner as at N. P. Junction, and at the falls of the Vermilion, northwest from Sudbury in Ontario, furnishing a strong lithological bond of idenity of age. These lumps were first noticed here by Dr. T. Sterry Hunt, on occasion of an excursion of the American Association for the Advancement of Science, from Minneapolis, in 1883. These calcareous lumps are of dark gray color within, approximating the color of the slates, but they are granular and crystalline. They decay superficially and become spongy, acquiring a darker shade. (Compare rock samples 1591, 1607 and 1616.)

The slate extends at least to Cloquet, and is all of the same formation, at least from the quarry of Dietz and Dugan. It dips in opposite directions, showing several great anticlinals, the inclination being frequently 75°--90°, and rarely less than 50°. This refers not to the cleavage, which traverses the sedimentation, but to the sedimentary bedding. The general color, when fresh, is purplish-black, but on weathering this varies from gray to greenish-gray, with fleckings of lighter, this lighter flecking appearing where the rock is of coarser grain. The calcareous lumps extend all the way to Cloquet.

*N. P. Junction*, Oct. 17. I have looked over this formation with a view of learning certainly whether it be of the Taconic or the Keewatin. I had rather expected to see some resemblance to the Keewatin, on looking it all over, but so far as the west side of the river is concerned, I do not think I can say I have seen any Keewatin. There are some portions of the Keewatin that resemble this rock, but so far as I have ever observed they are a very small and unimportant part, and are associated with lithological features on which they depend, which are wanting here. This is nearly all a true slate, with a cleavage oblique to the bedding, though in two instances I saw them coincident. The slate is not all suitable for scarcely acted at all at the beginning, or at least it left no records, and that force which transformed the lower materials into crystalline forms was different from and acted later than those which gave them origin. It is necessary also to account for a sudden cessation, or at least a remarkable reduction in the activity of volcanic forces just before the opening of the Taconic, and for that universal crumpling and almost vertical attitude which the Archean strata exhibit.

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Gunflint lake. In every respect, so far as color, structure, composition and tendency to decomposition, as well as associated rock-strata can indicate it, these are the same as those.

As between this slate and that seen at the crossing of the Vermilion river, northwest from Sudbury, there is a perfect correspondence, and there can be no question of idenity of stratigraphy. Here the tracing to the Taconic, through the parallelization by Irving and others, of the original Huronian with the Animikie is more unbroken, though more circuitous. The above notes pertain to the rocks seen on the west side of the river at N. P. Junction.

*Northern Pacific Junction*, Oct. 17, 1890. After writing the foregoing a re-examination was made of the prominent ridges of slate immediately at and east of the depot, but still west of the river, north of the railroad track. Here the first thing noticed was the manner of distribution of these limestone masses. There is a plain confirmation of the idea that they are the analogue of the limestone layers of the Gunflint region. Not only are they numerous, varying in size from a peck measure to a walnut, but they run in belts coincident with the sedimentary structure, and in one instance they make a continuous layer, somewhat nodular, that extends for 33 feet at least, and maintains a thickness of about two inches, but vanishes toward the east. The layer is marked by a rusty surface coating which is nothing but the rusty oxidation seen on such rock at Gunflint lake. As limestone it is not pure, but very firm, gray and slate-colored. Except for its weathering out rapidly it could hardly be distinguished on the rock surface. It makes numerous elongated, lenticular holes over the surface, the origin and significance of which were not noted in any previous visit to this locality.

Besides the old Thompson test of the slates, the test of the St. Paul and Duluth R. R., about two miles south of Cloquet, and the recent one of Dietz and Dugan, there is now being made what will be a most thorough test by the C. E. Nelson Lumber Company, of Cloquet, at about a mile and a half south of Knife Falls. It is near the railroad, where an east and west ravine crosses it. The plan is to make at first a shaft about 75 or 100 feet in depth for the purpose of proving the character of the rock at that depth below the surface.

On the east side of the river the graphite locality, mentioned by Schoolcraft, is on n e ¼, n e ¼, sec 31, lot 1, about 4 miles north of Thomson, near the river, and near a creek, which enters the river. It is now owned by H. H. Hawkins, C. d'Autremont Jr. and D. V. Scott. The vein in which graphite is found is about 12 inches wide. It amounts to but little. Some work has been done recently on the vein, the resulting excavation being about 20 feet deep. The vein itself is one of quartz, cutting the slates, and has much associated plumbaginous matter. Recent work was of no avail to show its importance. The formation here looks like the rock westward from Pigeon point on the international boundary.

A little below (but nearly opposite) the foot of the large island which is opposite the graphite locality, is a basic dyke about 25 feet wide, coming in diagonally across the river bank. It runs north 10° east, and is coarse-grained in general, but fine-grained at the side, having basaltified and hardened the slates. This may be in extension of a great dyke noted on the west side of the river some years ago not far from the slaty Fortress island.

The river roars with rapids much of the way, and at ¼ of a mile further south there is a fall of about six feet. At about two miles north from Thomson is a massive, light-weathering but gritty, rather coarse-grained stratum in this formation; and this also contains the rusty calcareous masses noticed in the fine-grained slates. This calcareous mass could hardly be distinguished from the rock in which it is embraced except for the rusty spot which it causes on the weathered surface (1616).

Apparently the old portage trail runs along near here, near the river, from Fond du Lac to Knife Falls. I imagined I put my foot in the same niches over the rock ridges that Schoolcraft, Houghton and Boutwell stepped on, and where thousands of furriers and Indians have stepped for more than 200 years on their trips from Winnipeg to Montreal.

The first rock-cut in gabbro, east of Thomson, is a short ¼ mile east of Short Line Park station, where the "Duluth deep well" was drilled about 1700 feet in search for gas. (See Bulletin No. 5). This is the station for old Fond du Lac, and a number of Indians here leave the train, with some half breeds, for that old town. They asserted that the old trail from Fond du Lac runs about four miles further east than where the graphite locality is known near the river, crossing the railroad (short line) at about one mile west of the Short Line Park station. This gabbro is like that at Rice's point, and the spur runs southwest from the main belt. There are also several other spurs further east. From this cut rises toward the east and northeast a marked precipitous range of gabbro. The track hugs the foot of this range with occasional cuts, until it has passed the head of a deep ravine, and then swings south to pass another spur, with several gabbro cuts further east as it descends to the terrace flats of the St. Louis river.

*At the station called Sargent,* a short distance east of Duluth, the usual "trap" of the region underlies the surface at the depth of a few feet. The excavations for water works are principally in red clay, but frequently encounter this rock, which is there well exposed by the blasting and cutting. It is reddish-brown, and in some places amygdaloidal with calcite, and at the same time has disseminated fine red crystals of some feldspar. On some favorable fractures this feldspar has the form of twinned tablets of some plagioclase, but generally it is not evidently twinned, but so crowded and compressed that no cleavage can be characterized, though evidently a cleavable mineral. It apparently also is disseminated in finer forms throughout the mass of the trap. The rock therefore is sparingly porphyritic, and conspicuously and coarsely amygdaloidal with calcite. 1615 is the above rock.

[NOTE. Most of the field notes of 1890 were incorporated in the report on the "Iron Ores of Minnesota," Bulletin VI, 1891. See also the accompanying list of rock samples].

# ADDITIONAL ROCK SAMPLES NUMBERED.

[TO ILLUSTRATE NOTES OF N. H. WINCHELL],

IN 1890.

1607. Calcareous, soft, rusty lumps. Dietz and Dugan's slate quarries, about three miles above N. P. Junction. (See also 1616.)

1608. From near the old saw mill, a short distance north of the the last. A square slate piece showing lime seams on each side—joints that cross the slates in too great frequency for the good of the economic outlook.

1609. A fragment from an almost unweathered lump of the calcareous concretions abounding in these slates, broken from the hard fresh slates at the old trial quarry of the St. Paul and Duluth R. R., about 1½ miles south of Cloquet.

1610. Sliver from the slate showing fine ripple marks. Coarser ripple marks and other water-marks are common.

1611. Chipping from one of the calcareous nodules from the slates at N. P. Junction east of the village, north of the east and west railroad. This came from about the same place as that from which Dr. Hunt obtained the specimens in which were thought to be remains of a keratose sponge.

1612. Chipping from one of the lighter-colored siliceous, thicker beds in the ridges, six inches thick, north and east from the R. R. junction.

1613. Same as 1612, from a layer 20 feet thick. When fresh this is dense.

1614. Graphite and quartzose slaty rock, from the "graphite vein," N. E. ¼, N. E. ¼, sec 31, lot 1, T 49-16.

1615. Slightly porphyritic, and amygdaloidal trap, from Sargent, east of Duluth, from the trenches dug for water-works.

1617. Samples of iron, from Camp's land, S. W. ¼, sec. 33, a mile southwest of Ely.

1618. Ore from the narrow magnetic belt on Camp's land, S. W. ¼, sec. 33, about a mile southwest of Ely. (Iron ores of Minnesota, page 202.)

1619. Loadstone ore said to have come from the same place as 1618. (Iron ores of Minnesota, page 202.)

1620. A "quicksand" which is encountered at the bottom of the pits in the Anderson location, near Ely. It is very fine-grained and clay like. Are the grains angular, and referable to disintegrated jaspilyte?

1621. In the greenstone of one of the ridges on the S. W. ¼, sec. 33, about a mile southwest from Ely, is the indefinite rock which has been described in this region—neither greenstone nor graywacke. In the midst of it is a harder and more siliceous area, which seems to be only a phase of it, represented by 1621.

1622. A boulder was taken out from one of the pits by Mr. Camp, which represents another phase of the greenstone, but this is not seen in place anywhere about here. It may have come from north of Long lake. It is one of those coarsely crystalline (fragmental) greenstones, with free quartz grains and pyrite, and seems to consist largely of plagioclase and hornblende.

1623. Globular and nodular mixture of the white kaolinic and red hematitic soft rock, the two not mingling so as to stain each other though in immediate contact. From the dump of the Chandler mine. This kaolin seems to be one of the very early constituents of the rocks of the region, and not the result of recent change.

1624. Fragment of the amygdaloidal scale that surrounds the volcanic bombs seen in the rock-cut at Ely, and some of the matrix.

1625. Some of the dark-green schistose rock that fills the interspaces between the bombs.

1626. A piece of the bomb from toward the centre, away from the amygdaloidal crust. (American Geologist. Vol. ix, p. 359.)

# III.

# FIELD OBSERVATIONS ON CERTAIN GRANITIC AREAS

## In Northeastern Minnesota.

BY ULYSSES SHERMAN GRANT.

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# INTRODUCTION.

In the summer of 1891 the writer, accompanied by Mr. Herbert R. Wood and one Indian canoeman, spent the greater part of the months of August and September in examining certain granitic areas in Lake and Cook counties, Minnesota. The areas visited are four in number, and may be distinguished as the following: (1) the Kawishiwi river area, which extends from the division of the Kawishiwi river in T. 63–10 west and southwest for a considerable distance; (2) the Snowbank lake area, which is mostly confined to the islands and shores of Snowbank lake; (3) the Kekequabic lake area, in the immediate vicinity of the lake of this name; (4) the Saganaga lake area, in which the larger part of Saganaga lake lies. The object of the examination was more to study the age and origin of these granite masses and to ascertain their relation to the surrounding rocks than to make any minute study of the structures and variations of the granites themselves.

The present paper is simply an account of the phenomena as seen in the field, supplemented by but a small amount of laboratory study. A number of the rocks, especially the normal facies of the different types, have been examined in thin section, and considerable progress has been made towards a systematic study of one of these areas—that of Kekequabic lake. The writer hopes in the near future to be able to give a more complete account of the different rocks of this interesting area, both stratagraphically and petrographically.

On account of the incomplete character of the work and the lack of sufficient time in the preparation of this report it is thought best not to give a detailed description of each area nor to make any generalizations concerning the region studied. However, it will not be amiss to say a few words as to the results reached thus far. In the parts of the four areas studied there has been seen no evidence of a transition from the semi-crystalline and crystalline schists to granite. On the other hand there is abundant evidence to prove the true irruptive nature of these granitic rocks into the surrounding sediments, notwithstanding the fact that these granites have been described as granitoid gneisses formed from the metamorphism of certain clastics and now seen to pass imperceptively into these same clastics.* The gneissic and so-called "bedded" structure in these rocks is not nearly as common as has been supposed, in fact the usual structure is truly granitic. The Kawishiwi river "granite," where studied, is a hornblende syenite, as is also that around Snowbank lake. The Saganaga granite is a very coarse hornblende granite. The granite around Kekequabic lake is a pyroxene granite, and associated with it is a peculiar pyroxene granite porphyry.

## PART I. RECORD OF FIELD OBSERVATIONS.

In giving the township and range in the following notes the township is always north, and the range is always west of the fourth principal meridian, Minnesota, unless stated otherwise. The bearings given refer to magnetic north, no correction having been made either for general or local variation. When giving the strike and dip of slates reference is always had to the lamination, unless otherwise stated. As a rule the edges of the different granite areas have been studied, as here only could the relations to the surrounding rocks be seen.

### KAWISHIWI RIVER AREA.

The examination of this area was confined entirely to its eastern end, and most of the notes were taken in the southern half of T. 63-10.

### *Pickerel lake.*

Pickerel lake† is a small body of water cut by the line between secs. 24 and 25, T. 63-11, and secs. 19 and 30, T. 63-10. The shore where visited was found to be made of a more or less massive rock, which in all the reports on this region has been called greenstone or greenstone-schist. From the little bay of the Kawishiwi river in the N. E. ¼ of S. W. ¼ sec. 25, T. 63-11, a portage leads to the southwest corner of this lake. The southern half of the portage shows angular blocks of mica-schist, probably not far removed from their original position, and the northern one-third of the portage is over a ridge of rather massive greenstone represented by Nos. 302, 303 and 304, the latter from the lake shore. No. 303 is, however, more like an altered graywacke and is quite schistose. The greenstone extends all along the south shore of the lake. It is shown by No. 305, which is very dark-green and schistose, and occurs just east of the portage, No. 306, more compact and silicious, and No. 307, which was taken from the outlet of the lake in the N. E. ¼ of N. W. ¼ sec 30, T. 63–10. At the east end of the lake just south of the section line the rock is green, very tough and massive; it presents the appearance of a consolidated volcanic ash (No. 308). Only one spot (S. W. ¼ of S. W. ¼ sec. 19, T. 63–10) on the north shore of the lake was examined; here the rock is a fine grained massive greenstone (No. 309).

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*15th (1886) Annual Report, pp. 199-204.

†The Chippewa name for this lake is Gi-nó-ses, which is the word for pickerel.

A section was made from this lake south along a trail, which is almost on the range line, to the Kawishiwi river. Several low ridges were crossed, the general trend of the ridges being east and west. Just south of the lake there are no outcrops seen, but a low ridge of fine grained compact greenstone (No. 299) is soon reached. This rock is cut in every direction by minute, branching, yellow and pink veins; it shows no structural lines, but appears perfectly massive. On going farther south the rock becomes schistose, this structure being vertical and running east and west. It is cut by a small dyke, four or five feet wide, of a quartzless porphyry (No. 300). This rock held a small piece of the greenstone, which is very schistose at the dyke walls, otherwise not being different from that farther away. The dyke runs almost east and west and was traced rather disconnectedly for fifty feet. No. 301 shows the contact of the two rocks. Farther south occur several outcrops of a finely laminated schistose rock (No. 310) which approaches a mica-schist. The lamniæ have been twisted considerably in places, but the general strike is east and west and the dip is vertical. This rock continues nearly to the quarter post, but just before reaching this a rather course grained red syenite is seen (No. 311). The hornblende is roughly arranged in elongated spots, thus giving to the rock a decidedly gneissic structure, which runs east and west and stands nearly vertical. Associated with this syenite are small areas of a fine grained granitic rock (No. 312). This gneissic syenite continues about half the distance from the quarter post to the Kawishiwi river and then assumes a darker, finer grained aspect (No. 313) with the hornblende much more abundant than in No. 311. It now contains fragments from one inch to several feet in length of a dark mica-schist (No. 314); these fragments are mostly lens-shaped and their outlines are distinct. The syenite also holds many veins, up to ten inches across, of a rather fine grained biotite granite (No. 315). At this place the gneissic structure in the syenite, the long axes of the mica-schist fragments and the general direction of the granitic veins are northwest and southeast. Mica-schist now extends to the river and also occurs on the little point in the S. W. ¼ of S. W. ¼ sec. 30, T. 63–10; here a little back from the shore is a low ridge of the schist (No. 316) which strikes 80° W. of N. and dips N. 65°. In it is an irregular vein of very fine granitic rock (No. 317).

### *Clearwater lake.*

Clearwater* lake lies almost entirely in sec. 32, T. 63–10, with a small bay projecting into the E. ½ of N. E. ¼ sec. 31. Excepting a small area at the northwest corner of the lake near the portage north to the Kawishiwi river, the shores are composed of reddish syenite which is quite constant in character. In the S. W. ¼ of N. W. ¼ sec. 32, the syenite shows an irregular flow structure, which is more evident here than elsewhere on the lake, although seen in several other places. It twists considerably, but stands about vertical and its general trend is east and west. No. 337 shows this structure very well, although the lines are not usually as near together and as distinct as on this specimen. The syenite of this lake is well represented by Nos. 338 and 339, the former coming from the same locality as No. 337, and the latter from the extreme northern end of the little bay that extends into the S, W. ¼ of S. E. ¼ sec. 29. The rock is microscopically a rather coarse grained aggregate of hornblende and reddish feldspar in about equal amounts.

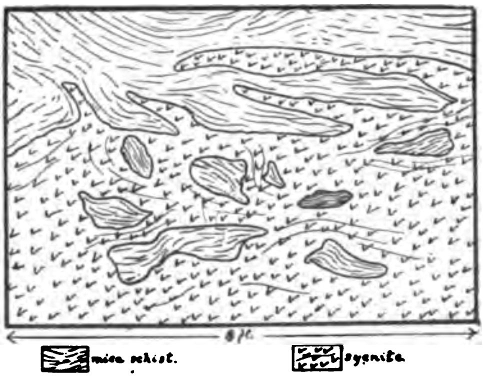

Fig. 1. Contact of syenite and mica-schist; N. E. ¼ N. E. ¼ sec. 31, T. 63-10. north shore of Clearwater lake.

Where the line between secs. 32 and 31 cuts the north shore of the lake the syenite is seen mixed in with mica-schist. See Fig. 1. The schist is much twisted and the syenite exhibits the flowage structure as shown by No. 337. Most of the syenite here is of the usual character, but in some areas it is of a finer grain (No. 340). Just west of this place the syenite and mica-schist are seen in contact. The schist is much disturbed and twisted and the dip and strike could not be accurately determined, but the general trend is a little south of east with a very high northerly dip. The contact is irregular, but sharp, and is shown in the specimens numbered 341. No. 342 is the syenite within a foot of the contact.

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*The Chippewa name is Gawaukamik.

At one place on the portage, running northwest from the lake, and in several places on the shore in the E. ½ of N. E. ¼ sec. 32, there is a dark green rock (No. 343) which is a coarse grained aggregate of hornblende with a small variable quantity of feldspar. It presents a very rough, jagged, weathered surface. It is cut by vein-like stringers of reddish syenite (No. 344) similar to the ordinary syenite of the region, by a gray variety (No. 345) of the same and by a small trap dyke (No. 346). The last is but four inches wide and was traced for fifteen feet; it is probably a very fine grained diabase. A section of No. 344, at the contact with the hornblende rock, shows the former to be composed of a granular aggregate of (1) an almost opaque feldspar, which, notwithstanding its alteration, shows some traces of polysynthetic twinning, (2) a fresh feldspar with abundant twinning lamellæ and (3) a few pieces of green hornblende; the two feldspars are in about equal amounts. The small part of the hornblende rock in the section is seen to be made up almost entirely of green, highly pleochroic hornblende; a small amount of the altered feldspar is also present. The two rocks are seen to be separated quite sharply even in thin section.

Mr. Wood examined the shores of the small lake in the N. ½ of sec. 31, T. 63–10, and found them to be composed of the same syenite as is seen on Clearwater lake. At the southwest corner of this small lake he found fragments of mica-schist embedded in the syenite.

### *South branch of the Kawishiwi river in T. 63–10 and T. 62–10.*

Going north from the river nearly on the line between secs. 5 and 6, T. 62–10, the syenite is seen to be cut by irregular small dykes or branching veins of a hornblende rock (No. 349) similar to that mentioned above (No. 343). These veins cut the syenite in every direction and their outlines are very sharp and distinct, especially on weathered surfaces. The syenite here varies somewhat, and as a rule is darker colored than that seen elsewhere in this vicinity; it is represented by Nos. 347 and 348. The syenite on the river shore near the above mentioned section line is also somewhat finer grained and darker than is usual (Nos. 350 and 351). On the north shore of the river in the S. W. ¼ N. W. ¼ sec. 5, T. 62-10, is a rather coarse grained diorite (Nos. 352, 353 and 354); it is more than half made up of green hornblende, and the feldspar is white or grayish,—the rock thus standing in sharp contrast to the surrounding syenite. The relations of the two rocks were not seen here, but the diorite probably is the same as the hornblende vein rocks described above, although in this place the diorite may possibly represent a basic facies of the syenite.

No. 355, from the S. E. ¼ of N. E. ¼ sec. 5, T. 62-10, well represents the syenite in this immediate vicinity; it is a rock of medium grain, reddish in color, and composed of a flesh-colored to reddish feldspar and hornblende; the latter makes up about one-third of the rock. Going south along the river in secs. 5, 4 and 9, the syenite, as a rule, becomes finer grained and in some places holds biotite instead of hornblende.

At the north end of the portage, N. W. ¼ of S. W. ¼ sec. 9, T. 62-10, just at the water's edge, is an outcrop of medium grained hornblende granite (No. 356); the quartz makes up about one-fourth of the rock. This is evidently a part of the syenite of the region, but is the first seen that contains macroscopic quartz grains in any amount. About one-third way across the portage the coarse grained grey gabbro (No. 357) common to this region is seen. This was traced west of the portage to within 200 feet of the syenite, but low ground with no exposures intervened between the two rocks. Here the syenite is fine grained and micaceous, as is shown by Nos. 358 and 359, the former being more properly a biotite granite. The syenite is cut by small dykes or veins of a fine grained red aplite (No. 360) composed almost entirely of a red feldspar and quartz. The gabbro retained its coarse grained character as near to the syenite as it was found.

The east side of the rapids, in S. W. ¼ sec. 9, T. 62-10, was carefully examined in order to study the relations of the syenite and gabbro, but nothing conclusive was seen. The syenite here is shown by Nos. 361 and 362, both rather fine grained and micaceous. Between the syenite and gabbro were found Nos. 363 and 364, the former partaking of the characters of the syenite and containing large quantities of a dark mineral, probably hornblende; the latter is finer grained and very dark in color. There were no continuous exposures connecting the syenite and gabbro. At the foot of the rapids I found several angular blocks, apparently not far removed from their original position, of a fine grained purplish rock, probably a porphyrite (No. 365). Mr. Wood examined the west side of the rapids, but could not find the gabbro and syenite near each other.

The west shore of the river in secs. 34, 35 and 26, T. 63–10, is made up of the ordinary syenite, which varies somewhat in the amount of hornblende it contains, as seen in Nos. 366 and 367. No. 366 is quite dark in color and the hornblende makes up more than one-half of the rock,—this facies, however, is exceptional. No. 367 is much lighter colored and is at least three-fourths composed of feldspar. No. 368, from the S. W. ¼ of sec. 34, fairly shows the syenite along this shore; it is composed of flesh-colored to red feldspar and black hornblende, the latter making up perhaps one-third of the rock. This rock is of a medium coarse grain. In section it is seen to be a granitic aggregate of orthoclase, hornblende and quartz. The orthoclase is gray and usually shows a cloudiness due to alteration; a few of the grains show polysynthetic twinning lamellæ. The hornblende is the ordinary green, highly pleochroic variety, and is completely allotriomorphic; it has altered in some places to chlorite, but elsewhere appears to be quite fresh. Quartz is scattered through the whole section, but is not noticeable macroscopically; it presents the characters of ordinary granitic quartz. It occurs oftentimes in polysomatic areas, and a large number of the grains show decided undulatory extinction. The quartz makes up less than ten per cent. of the whole rock. Apatite, sphene and magnetite are the accessory minerals; they all occur in only small amount. The apatite is in both short, stout and long, slender prisms. The sphene and magnetite show no characteristic crystal outlines.

Careful search was made for mica-schist along this shore, but no trace of it was found.

### *North branch of the Kawishiwi river in T. 63-10 and sec. 19, T. 63-9.*

Mr. Wood went south from the river about on the west line of sec. 31, T. 63-10, for about half a mile. He reported mica-schist (No. 318) all the way, but in a few places, especially just south of the river, a green schistose rock (No. 319), probably a condition of the greenstone, was seen. From this section line he went northeast to the bay in the S. E. ¼ of S. W. ¼ of sec. 30, but saw no rock in situ except the mica-schist.

The little promontory on the south side of the river in the N. E. ¼ of S. W. ¼ sec. 30 is made up of red syenite (No. 320). This is a rather coarse grained rock and in some places it shows a distinct gneissic arrangement of the feldspar and hornblende. It is cut by a dyke of a dark hornblendic rock (No. 321); this dyke is vertical and varies from ten inches to two feet in width; it runs a little south of east and was traced for fifty feet. The west end of the portage across this promontory is in the mica-schist, but the line between the schist and syenite soon crosses the portage and runs a little south of the bay in the S. W. ¼ of S. E. ¼ of sec. 30. The two rocks were seen in actual contact just north of the portage; there was no transition from one to the other, the line between them being quite distinct. The syenite was finer grained and grayer in color near the contact; this is shown by Nos. 322 to 325 which were taken within a distance of two feet. The last one was touching No. 326 which is unmistakably part of the mica-schist. No. 327 is the mica-schist near to the last and No. 328 represents it a few feet from the seyenite. The line of contact was vertical and rather irregular, the syenite usually followed the direction of the schistosity, but in some places broke across it for a few inches. On the portage a few loose blocks were seen which showed both rocks in sharp contact (No. 329); however, it is not certain that these blocks had not been moved some distance.

The west shore of the river in the E. ½ of sec. 30 is almost all syenite, but about the center of the shore line some mica-schist is seen mixed with the syenite. The latter extends in vein-like branches into the former and also encloses pieces of it. Mr. Wood went from this place west to the stream that enters the river in the S. E. ¼ of N. W. ¼ sec. 30 and reported syenite all the way. He also found a fine grained diorite dyke (No. 330) in the syenite; this ran north and south, was ten feet in width and was traced for sixty feet. He also reported many inclusions in the syenite, of which Nos. 331 and 332 are samples; the former is a dark, rather fine grained diorite, the latter a fine grained silicious schist.

At the rapids in the S. E. ¼ of N. E. ¼ sec. 30 the river flows over angular syenite fragments. On the east shore of the river in the same $\frac{1}{16}$ section mica-schist and syenite are seen in contact. There is not as sharp a line here between the two rocks as at the above described locality; the change from one to the other occurs within one or two inches; Nos. 333 to 336 represent this change, the first three of these were taken within a distance of three inches.

The point in the N. E. ¼ of sec. 26 is made up of the ordinary coarse red syenite of the region, but on the north side of this point, about the center of the section, is a dark, rather coarse grained diorite (No. 369). Macroscopically this is seen to consist of hornblende and a white feldspar, the former in larger amount than the latter. Under the microscope the feldspar is seen to be very highly altered and in only a few places is it fresh enough to show traces of polysynthetic twinning; the hornblende is of the ordinary green variety and is extensively changed to chlorite and some few flakes of biotite. The relation of this diorite to the syenite of the region was not determined, but the impression is that this is a basic facies of the syenite. The diorite is cut by a fine grained trap dyke (No. 370) and also by a light reddish fine grained granite (No. 371). The last appears in quite an amount and extends along the south shore of the river as far as the west end of the island in the S. E. ¼ of N. W. ¼ sec. 26. A short distance beyond this the diorite is seen in contact with a fine grained gray granite (No. 372), which is probably a part of the same rock as No. 371. The diorite here (No. 373) has both red and white feldspar and seems to be rather intermediate between the ordinary syenite and the diorite described above (No. 369), thus indicating the probable identity of the two rocks. No. 374 shows the two rocks (Nos. 372 and 373) in contact; the line is very sharp and distinct, but at this place nothing was seen to indicate the relative ages of the two. The diorite continues along the shore in the S. W. ¼ of sec. 26, and in some places becomes lighter colored as shown by No. 375. In a westerly facing diorite cliff (N. W. ¼ of S. W. ¼ sec. 26) are three small dykes, about a foot wide, running diagonally up the cliff towards the north. No. 376 was taken from one of these dykes; it is a dark, rather fine grained rock, composed almost entirely of hornblende.

At the southern end of the bay in S. W. ¼ of S. W. ¼ sec. 26 the syenite again occurs. It is here represented by No. 377, which has most of its hornblende altered to chlorite. At this place a small piece of finely laminated gneiss (No. 378) was found enclosed in the syenite. The western shore in the E. ½ of sec. 27 is composed of the syenite similar to No. 377.

Just north of the river on the line between sec. 21 and 22 is a low outcrop of aphanitic greenstone (No. 379). It is much cracked and fissured and shows an indistinct, coarse schistose structure, which is vertical and runs east and west. Farther north from the lake on the same section line is an outcrop of very massive greenstone (No. 380), which is of coarser grain and grayer color than that last mentioned. This is seen in contact with a quartz porphyry (No. 381) which holds a few quartz crystals, many white feldspars and numerous small pyrite grains in a grayish groundmass. The contact line between the two rocks is sharp, stands vertical and runs north and south. Only a small area of the quartz porphyry was exposed; it probably forms a dyke in the greenstone. Continuing northward on this section line for about three-quarters of a mile from the river, several ridges of massive greenstone are crossed. No. 382 shows the most massive and coarse grained condition of this greenstone.

On the north shore of the river, just west of the line between secs. 27 and 28 are several outcrops of a fissured greenstone similar to No. 379. Farther west on the same shore and just east of the portage is a large outcrop of a finely laminated graywacke-like rock (No. 383); it is in some places much coarser grained, as shown by No. 384. The strike is N. 75° E., and the dip from 75° to 80° S. On the north side of the river and between the portage and the head of the rapids (N. E. ¼ of N. E. ¼ sec. 28) a rock similar to the last, except that it is more massive in appearance, is found. Here on some of the weathered surfaces an indistinct vertical lamination is seen; this varies somewhat in direction but the general trend appears to be about 25° E. of N. Nos. 385 and 386 represent the rock at this place. This laminated rock belongs to a fragmental series which is here in contact with syenite. This series is made up of rocks which are very often graywackes and often mica-schists, with all intermediate stages; and there are also some facies that are more like coarse grits, silicious schists and even sericitic schists. These different facies constantly intergrade. For convenience the term "graywacke-like rock" will be used for the finer grained and less crystalline rocks of this series. Mica-schist and gneiss will be used to refer to parts of the same series which are more highly altered.

A short distance from the east end of the above mentioned portage rock similar to Nos. 383 and 384 is found; here the lamination is distinct; the strike is 72° E. of N. and the dip S. 85°. A little further west the syenite (No. 387) occurs. It has a vertical gneissic structure which is very evident on weathered surfaces; this strikes on the average about 70° E. of N., but varies as much as 15° either side of this direction. This syenite occurs directly in the strike of the last mentioned outcrop of laminated graywacke-like rock.

About half way across the portage is a soft fissile greenstone or greenstone schist (No. 388). In this is a series of parallel veinings which coincide with the direction of the cleavage planes in the rock; both stand vertical and strike N. 80° E. A few feet south of this the ordinary syenite is seen. There is almost a continuous exposure between the two rocks, and samples illustrating the change from one to the other were taken. No. 389, from eight inches south of 388; 390 was eight inches further south; then within a foot came 391 and 392; two feet further was 393, and three feet from this 394, which grades into the ordinary syenite represented by No. 387. The change from the greenstone schist to the syenite is first noticed by a small amount of red feldspar in the greenstone; the feldspar gradually increases in amount and the green material decreases until the ordinary syenite is reached. The schistose structure in the greenstone and the gneissic structure in the syenite are parallel and grade into each other as the two rocks intermingle. One hundred feet north of this place is a low southerly facing bluff of greenstone, much cracked and fissured. On the weathered surfaces it shows a series of reddish, vertical veinings whose average strike is N. 70° E., and almost at right angles to this are two nearly parallel systems of joints which cut the rock into small elongated diamond-shaped areas.* Specimen No. 395 shows this jointing fairly well.

Further west on the portage trail more of the greenstone is seen. Then the syenite appears again, and beyond this, not more than 200 yards east of the west end of the portage, the graywacke-like rock again appears. It has the distinct lamination seen before and strikes N. 60° E.; the dip varies from 80° towards the north of this line to 70° on the other side. The syenite occurs on the portage directly in the strike of this rock and not more than 150 yards east of it. The laminated rock is seen in contact with the syenite, which here lies north of it, about 50 yards north of the stream. It is here shown by No. 395A, which has considerable sericitic material developed in it. Eight inches north of this occurs the actual contact between the two rocks; the hand specimens No. 396 show this. The line between the two is distinct, but the syenite holds considerable of the material of the other rock. Six inches north of this the syenite is shown by No. 397; seven inches beyond by No. 398; eighteen inches from this by No. 399, and four feet further north it has its usual character and appearance, as shown by No. 400. At this place the contact was along the strike of the laminated rock and there is nothing to show their relative ages. The syenite now extends northward for thirty feet, where it disappears under the soil as it does just to the west of this place. Boulders of massive greenstone occur just north of the syenite, but the greenstone is not seen certainly in place until a low ridge of it (No. 401) is reached fifty feet north of the syenite.

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*Compare the diagrams of jointing and schistose structure in the greenstones of the Menominee river, Michigan; Bul. 62, U. S. Geol. Survey, p. 128.

The high ridge, running east and west through the N. ½ of N. W. ¼ sec. 28, is composed of massive greenstone. In places it is cut by irregular branching dykes of gray quartz porphyry. These dykes vary from an inch up to more than a dozen feet across. The principal and largest one runs about east and west along the southern edge of the top of the ridge and varies considerably in width. The contact between the porphyry and the greenstone is sharp and there is no intermingling of the two rocks. At the contact the greenstone does not appear to be much changed except that it is more broken and fissured. Pieces of the greenstone are included in the dyke. Nos. 402 and 403 represent this porphyry; the former was taken within three inches of the edge of the dyke, and the latter about four feet from the edge. This rock has a grayish groundmass in which are imbedded a few quartz grains and numerous flesh-colored and blood-red feldspars The quartz is more plentiful near the edge of the dyke (No. 402). In places the rock contains minute cavities, apparently formed by the weathering out of certain constituents of the rock. Under the microscope the rock is seen to have a micrograniticgroundmass of rather variable grain. In this are feldspars of all sizes up to pieces over a quarter of an inch in length. The crystal outlines of the feldspars are not usually distinct and most of them show no planes at all, being pieces with irregular outlines. Many of the feldspars show polysynthetic twinning lamellæ, and a large number do not. Alteration to sericite is quite common, and in some cracks and areas of considerable size in the groundmass sericite has been developed in large amount. Secondary calcite is also present. No distinction between the flesh-colored and the blood-red feldspars can be made in ordinary section,—they both appear colorless; and as yet no oriented sections of the two kinds have been studied; they appear very distinct in the hand specimen. Scattered through the rock are colorless to greenish secondary needles of chlorite or hornblende. A few areas of green hornblende, more or less altered, also occur, but it is not possible to say whether or not this hornblende was the form of the original ferro-magnesian constituent of the rock. Sphene and apatite are present in small amount. Large quartz grains are not present in the sections examined, although macroscopic grains are often seen in the hand specimens collected.

On going south from the stream into the S. E. ¼ of N. W. ¼ sec. 28, the graywacke-like rock is seen showing the characteristic lamination. Soon this rock begins to grow more crystalline, and this character becomes more and more pronounced as one proceeds southward. No. 404 shows this more crystalline facies, but in this the lamination is still distinctly preserved. Interbedded with this are beds of a less crystalline character, as shown by No. 405, which is very similar to the mica-schist found to the west in sec. 30, already described. Other facies of this rock are shown by Nos. 406, 407 and 408, which are all completely crystalline. The first of these is a distinct gneiss, and the latter show no gneissic structure, even on the most favorable weathered surfaces. Macroscopically these three specimens are seen to be composed of quartz, a light colored feldspar, biotite and some little hornblende. These rocks, while completely crystalline, can in no wise be separated from the less crystalline facies and the graywacke-like rocks already mentioned several times. They are interbedded in bands from one-half inch to two feet in thickness,—the more crystalline always in the thicker beds. They seem to grade into each other across the the strike, and in some places the less crystalline is replaced along the strike by the more crystalline,—the former fading out into the latter. The most crystalline facies contain many black lens-shaped pieces of black diorite (No. 409); these pieces are composed mostly of hornblende with some little white feldspar. The exposures above described extend south from the stream for a quarter of a mile, and beyond this is low swampy ground with no exposures. The strike at the most southerly place seen was N. 70° E., and the dip vertical or very steep toward the south.

A narrow belt of syenite (No. 410) extends along the north shore of the river in the N. ½ of N. E. ¼ sec. 29. Just north of the syenite is a range of greenstone hills running east and west. In some places the two rocks were seen within fifty feet of each other, but at no place was the junction between them seen. The syenite rises in a bold bluff at the portage in the W. ½ of N.W. ¼ of N.E. ¼ sec. 29. About one-quarter of a mile east of this portage the greenstone is cut by an irregular dyke of gray quartz porphyry (No. 411). This dyke where examined is three to ten feet wide and has a general east and west direction. It was also seen, but not visited, in the greenstone both east and west of this locality. This dyke is probably a westward continuation of that already described from the N. ½ of N. W. ¼ of sec. 28.

Coming south from the river about on the line between secs. 28 and 29, the laminated rock and gneiss similar to that described above (Nos. 404 to 408) are seen in many exposures. About one-third of a mile from the river the syenite suddenly appears. It was first seen as a belt, 100 feet in width, running parallel with the gneiss which appears on both sides of it. The gneiss preserves its usual character and distinct alternation of different bands clear to the syenite. No. 420 shows this rock within a few feet of the syenite. Nos. 421 and 422 come from within three and one inches respectively of the syenite; the latter is some more coarsely crystallized and contains many distinct hornblende grains and some red feldspar. No. 423 shows the two rocks together; the line between them is quite sharp and distinct. No. 424 is the syenite just beyond No. 423; it is quite gneissic in structure. The strike of the gneiss is N. 60° E., and the gneissic structure of the syenite stands parallel to this; the dip is 5° either side of the vertical. In some places the line between the two rocks, instead of running with the lamination, runs across the strike for a few inches. In other places the syenite is more completely granitic in structure, as shown by No. 425. A short distance south of this the gneiss is much contorted and is cut by stringers, two to three feet across, of the syenite; some of these run with the lamination of the gneiss and others cut across it. There is no gradation from the gneiss to the syenite; the line between the two is clear and sharp. Further south the syenite becomes the prevailing rock, and in many places it holds lenticular masses of the gneiss.

On the south shore of the river just west of the line between secs. 28 and 29 the laminated rock is seen. Still further west, about half way from this section line to the rapids, which are about in the N. W. ¼ of N. E. ¼ sec. 29, the syenite again appears, but less than 200 feet south from the shore it comes in contact with the laminated rock. The junction here is along the strike of the laminated rock and the syenite was not seen cutting across the strike. The line between the two was distinct and easily seen on weathered surfaces. From the rapids just mentioned west to the east line of sec. 30 the laminated rock occurs on the south shore and a high bluff of it is seen just south of the river on this section line. The little bay in the N. E. ¼ of N. E. ¼ sec. 30 has syenite on its south and greenstone on its north shore.

Mr. Wood went south from the river about on the line between secs. 29 and 30. He found the laminated rock in place all the way until nearly half a mile from the river, when the syenite was seen. No. 426 shows the laminated rock, which here approaches a mica-schist, and No. 427 is more accurately a mica-schist. This latter facies of the rock was that most commonly seen, but that seen nearest the syenite was more like No. 426.

The north shore of the river, in the N. ½ of N. W. ¼ sec. 29, is made of greenstone, but the syenite comes in at the water's edge just west of the portage in the eastern edge of this quarter section. I went north from the river on the west line of this section for one-third mile, but found no rock except massive greenstone, of which several exposures were seen. About one-fourth of a mile east of this line and just north of the river the greenstone is cut by a dyke of reddish fine grained rock (No. 428) resembling a syenite porphyry. The dyke has an east and west direction and was traced for fifty feet. The sides of it were covered by soil, and as far as seen it was not more than ten feet wide.

The point on the south side of the river, in the W. ½ of N. W. ¼ of N. W. ¼ sec. 27, is made up of the laminated rock* and is well shown by the specimens already described,—Nos. 383 to 386. The strike varies from N. 30° E. to 45 E., and the dip from 75° to 80° S. E. Along the shore just west of this point the laminæ are much contorted. The point on the north side of the little bay in the same $\frac{1}{16}$ section is also made of the same rock. The small island in this bay is composed mostly of the syenite, but the northern side has a little of the laminated rock. Near the syenite this rock changes, becoming more crystalline and acquiring some reddish feldspar (Nos. 429, 430 and 431); but this condition exists only within a few inches of the syenite, in fact the syenite, as shown by No. 432, is seen within six inches of the above specimens. The junction between the two is easily seen as a pretty distinct line on weathered surfaces. Small pieces of the laminated rock were found in the syenite; No. 433 is from one of these. On the shore just east of this the syenite is intimately mixed with the laminated rock; still the line between the two is distinct and the syenite seems to have enclosed pieces of the other rock. In one place the syenite holds a small area of a dark compact mica-schist (No. 434), which is really part of the laminated rock, and shows lamination in favorable places. No. 435 shows this rock and the syenite together; they are marked off from each other by a sharp line.

The laminated rock is again seen on both points of the promontory in the N. E. ¼ of N. W. ¼ sec. 27, but the syenite appears on the western shore of the little bay in this $\frac{1}{16}$ section and also on the south and east sides of it. At the southeastern corner of this bay the rock has a decidedly schistose structure and there are alternating bands of schistose syenite (No. 436) and rock similar to Nos. 429 and 431 which appears to be an altered condition of the laminated rock; this is shown by Nos. 437 and 438. These bands of syenite and Nos. 437 and 438 vary from one inch to one foot in width, and they are parallel to the schistosity of both rocks. This is N. 40° E. and the dip nearly vertical. Nos. 437 and 438, while still retaining considerable of the sericitic material, have large quantities of reddish feldspar and some hornblende developed in them. Between these bands and almost always running parallel with them are vein-like forms of a fine grained pinkish granitic rock (No. 439) holding flesh colored feldspar phenocrysts. These veins vary from one to ten inches across and rapidly change their thickness in a short distance. They are also frequently faulted.

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*This is the rock described by N. H. Winchell in the 15th (1886) Annual Report, p. 362, under No 989.

On the north shore of the river in the N. W. ¼ of N. W. ¼ sec. 27 the laminated rock is found, and just north of this is a belt of syenite 150 feet wide, separating this rock from the greenstone. The junction of the syenite and laminated rock was seen in one place; the phenomena at the contact are the same as those already described under Nos. 395A to 400. The line between the two rocks runs parallel with the strike of the laminated rock and is quite easily distinguished. The syenite is also seen in contact with the greenstone; the change from one rock to the other occupies one or two feet and is essentially the same as that described above under Nos. 388 to 394. In some places in this vicinity the syenite, especially when in close proximity to the greenstone, becomes very schistose, as is shown by No. 440, which is dark colored and shows a decidedly gneissic structure; but generally in this 1/16 section the syenite is dark, massive and chloritic (No. 441). The syenite extends along the north shore from this place to the small bay in the S. E. ¼ of S. E. ¼ sec. 22. It forms only a narrow belt between the river and the greenstone ridge just north of it. Along this shore the syenite varies from a massive state, similar to No. 432, to a more chloritic (No. 441) and schistose condition (No. 440).

The island in the middle of the river just north of the west end of the promontory, in the N. E. ¼ of N. W. ¼ sec. 27, is composed entirely of the graywacke-like rock. The lamination is very pronounced and the strike is quite constant, being about N. 63° E.; the dip is nearly vertical. This strike would carry the rock into the north shore of the river less than a quarter of a mile east of the island, but there the syenite is seen and there is no sign of the graywacke-like rock.

On the little bay, in the S. E. ¼ of S. E. ¼ sec. 22, the graywacke-like rock is again seen just north of the south line of this section. The lamination is very distinct, and, while varying some, has a general northeasterly strike. A short distance south of this the syenite appears and extends along the north side and to the end of the point which makes the southern side of this bay. The graywacke-like rock makes up the southern half of this point; it is much twisted and crumpled. Its junction with the syenite was seen in one place; the line between this (No. 442) and the syenite (massive and similar to No. 432) was distinct. Just at the contact the graywacke-like rock showed distinct lamination in but a few small areas and here it faded out in a short distance. Away from the contact the lamination was very evident, though much twisted, and the rock was more like Nos. 383 and 384. The massive syenite is seen again on this point just east and west of the line between secs. 26 and 27.

In the N.W. ¼ of N. W. ¼ of N.W. ¼ sec. 26, the syenite is found on the shore. Just north of it the graywacke-like rock is seen; this becomes somewhat more crystalline, as shown by Nos. 443 and 444, and it seems to pass gradually into No. 445, which is a distinct gray gneiss. However, this gneiss was seen to hold sharply defined lenticular pieces of rock similar to some facies of the greenstone. No. 446 shows the gneiss and part of one of the lenticular pieces in it. The junction of the gneiss and syenite was not seen. The syenite here presents a decidedly gneissic structure, but this grades into the more massive facies within two or three feet. The phenomena here seem to be about the same as those described under Nos. 404 to 409; the gneiss (No. 445) is apparently a changed condition of the graywacke-like rock, although in some places the two are separated by a sharp line. Fifteen feet north of this the graywacke-like rock again appears; it is nearly vertical, and, while bent in some places, there is a decided general strike of N. 60° E. At times the rock is similar to Nos. 383 and 384, and again like No. 443. This graywacke-like rock continues northward for about 200 feet and then the syenite occurs. The two are separated by low ground with no exposures.

The syenite continues northeastwardly along the northwest shore of this bay (N. ½ of N. W. ¼ sec. 26) for some distance, and in it is a band of the graywacke-like rock ten feet wide. This is sharply marked off from the syenite on each side, and is distinctly laminated, striking northeast. In some places this band is similar to No. 443, but the most of it is mica-schist, as shown by No. 447. On the north side of this bay hills of greenstone are seen in the N. W. ¼ of N. W. ¼ sec. 26. The greenstone and syenite were seen within fifty feet of each other, but the junction was not found. The syenite becomes schistose and chloritic near the greenstone, as has been described farther to the west. Within 300 feet of the greenstone the syenite holds irregular sharply outlined pieces of the geenstone, which are from one to ten feet in diameter. On the weathered surfaces these pieces very closely resemble the greenstone in the hills just to the north, but on freshly broken surfaces the rock is seen to be slightly darker than the greenstone in the hills. No. 448 is from one of these pieces in the syenite. The greenstone in the hills near the syenite has a schistose structure, as shown by No. 449. This is twisted and somewhat irregular, but the general strike is N. 65° E., and the dip about vertical. The rock is lighter in color than the ordinary greenstone and contains some feldspar which weathers reddish. A short distance to the east the greenstone assumes the characteristic green color seen farther to the west, but the schistose structure does not altogether disappear. On the eastern side of the small point on the north shore of this bay the syenite occurs in a low outcrop. It is here in contact with the graywacke-like rock, but seems to enclose masses of this rock. The syenite here is mostly massive, but in a few places shows a gneissic structure which runs northeastwardly. There are pieces (a foot or so in length) of the graywacke-like rock enclosed in the syenite; most of these are facies of the rock approaching mica-schist. These pieces are mostly irregularly lenticular in shape and the lamination is parallel with their long axes, which usually lie in a northeasterly direction. Syenite occurs on the east shore of this bay.

The shores of the little bay which lies partly in the extreme southern part of sec. 23 are lined with syenite of the ordinary massive kind. About 100 yards north of the northwest corner of the bay is a hill of syenite which presents the schistose and chloritic character seen several times in close proximity to the greenstone. At the extreme eastern end of the bay the syenite is seen in contact with a dark diorite (No. 450), which is spotted by large blotches of hornblende. The contact line is sharp, as shown by No. 451, and neither of the rocks appears changed at the contact. The syenite is cut, on the eastern shores of the bay, by a coarse grained pegmatite (No. 452). This consists of large flesh-colored feldspars and small quartz grains, and often shows a true pegmatitic structure.

From this bay to the rapids, in the E. ½ of S. E. ¼ sec. 24, the north shore of the river has numerous outcrops of the ordinary massive syenite. No mica-schist or graywacke-like rock was seen along this shore, although special search was made for them.

On the south shore of the river, in the N. W. ¼ of sec. 25, there is a westerly facing gabbro cliff. On the face of the cliff was a small area, a foot square, of a reddish syenite bearing much biotite;

the specimen collected (No. 460) shows this rock and the gabbro. No other rock, except the gabbro, was found on the cliff. Just at the foot of the cliff was a large block of gray syenite (No. 461) and several small red syenite fragments (No. 462); these looked as if they had been broken off from the face of the cliff. This is possibly the line of juction between the syenite and the gabbro, but nothing more than above stated could be seen. The gabbro was the ordinary coarse grained facies.

The syenite of sec. 26 varies a little from that described from sec. 27. It is represented by No. 463, which is somewhat finer grained than the ordinary facies and is lighter in color, being more of a gray than a sed syenite, but on weathering it takes on a reddish color.

The river in the S. W. ¼ of sec. 19, T. 63–9, has two rapid channels around a small island, not shown on the township plat. The portage is along the south shore of the southern channel. At the east end of this portage gray syenite, similar to No. 463, occurs. Just beyond the portage and on the south shore of the island is a dark rock (No. 464) which seems to be intermediate between the gabbro and the syenite. It is a very compact rock of medium grain and uniform dark color, and on a freshly fractured surface shows in places yellowish color due to minute cracks; on weathered surfaces it has the appearance of the gabbro. This rock grades into the syenite (No. 467) through Nos. 465 and 466. The syenite was found at only one place, and that at the foot of a low cliff; the change from No. 464 to the syenite occupies two or three feet. This seems to be the junction of the gabbro and the syenite, but no true gabbro was found on the island, and it is not certain that No. 464 does represent the contact facies of the gabbro. Near the eastern end of the island gray syenite, shown by No. 469, is again seen. The ordinary coarse grained gabbro (No. 468) occurs on the south shore of the river just opposite this island, and on this shore no syenite was found. From this island the syenite continues along the west side of the river to the western end of the little bay in the S. E. ¼ of N. W. ¼ sec. 19, T. 63–9. The only exception to this is that on the south side of the point about the center of sec. 19, T. 63–9, the gabbro, similar to No. 468, is seen in a low outcrop. Thirty feet north of this gabbro is a gray rock (No. 470) which seems to be intermediate between the gabbro and the syenite. And 100 feet north of this the syenite is again seen. There is no continuous exposure between this syenite and the gabbro mentioned above. In places on a little island, which lies just off the end of this point, the syenite has a gneissic structure which stands about vertical and strikes N. 40° E.

On the north side of the bay, in the S. E. ¼ of N. W. ¼ sec. 19, T. 63-9, are many outcrops of a very fine grained, aphanitic grayish rock. It is shown by Nos. 471 and 472. This is apparently a facies of the greenstone.* It continues for an eighth of a mile, and probably much farther, north from the river. This rock continues along the north shore of the river for about a mile from this bay. On the line between secs. 19 and 20, a few rods back from the water (north shore of river), is an exposure of a fine grained massive diorite (No. 473). This was not, as far as seen, sharply separated from the rock shown by Nos. 471 and 472. Greenstone, or a rock intermediate between the greenstone and this diorite, was traced north on this section line for about a third of a mile.

### *Small lakes in T. 63-10, north of the Kawishiwi river.*

Starting from the river, on the line between secs. 28 and 29, is a portage which runs north to a narrow lake, which lies in secs. 15, 16, 20 and 21. The portage crosses several greenstone ridges. These present an extremely massive appearance; this is especially noticeable towards the north end of the portage. No. 412 fairly represents this greenstone; it is a dark green aphanitic rock; it was taken from an outcrop on the portage about an eighth of a mile north of the section corner. Greenstone of the same massive kind, with no evidence of schistosity or lamination, extends along the shores of this lake in section 20. At the west end of the lake a dyke of gray granite porphyry (No. 413) cuts the greenstone. The general direction of the dyke is east and west, but not enough of it was exposed to show the exact width, though this is probably not more than fifteen feet. In the rock are many quartz and feldspar phenocrysts, some of the latter being a half an inch in length. Macroscopically this rock closely resembles No. 417, which will be described more in detail. A small island, in the W. ½ of S. W. ¼ of N. W. ¼ sec. 21, also shows more of this granite porphyry. Greenstone extends along the north shore in sec. 21, but on the point, in the N. W. ¼ of N. E. ¼ of the same section, there is a bluff of a fine grained red-weathering siliceous rock (No. 414), which is probably a facies of quartz porphyry. Just north of this bluff the greenstone occurs, but the junction of the two rocks was not seen. Greenstone appears to make the rest of the lake shore, but on the east side of the little bay (south shore of the lake), in the W. ½ of N. E. ¼ sec. 21, a dyke of quartz porphyry is seen cutting the greenstone. This dyke is fifty feet wide, stands vertical and strikes a little north of west; this strike would carry it directly into the rock No. 414, mentioned above, which is probably a continuation of this dyke. The contact between the greenstone and quartz porphyry is sharp and distinct, and the former does not seem to be especially altered near this line. The centre of the dyke is much coarser grained than the edge. No. 415 shows the greenstone within two inches of the dyke; No. 416 is the quartz porphyry two inches from the edge of the dyke, and No. 417 is the same from the centre of the dyke. The quartz porphyry (No. 417) is of a general pinkish color; it contains many quartz and feldspar phenocrysts, the latter being white and flesh-colored. A few small specks of a dark mineral are also present. The rock seems to the unaided eye to have no unindividualized ground-mass, but microscopically the rock shows a decided micrographitic ground-mass of rather small but irregular grain. Imbedded in this are numerous feldspar phenocrysts of all sizes up to those nearly half an inch in length. Most of these feldspars show their crystallographic outlines on all sides, but some few appear as fragments partially bounded by crystal planes. Zonal structure is quite common, and about half of the individuals show polysynthetic twinning lamellæ. Quartz individuals of good size are also present, but are not nearly as abundant as the feldspars. The quartzes are all corroded and show no crystal faces, and they frequently have large embayments filled in with the ground-mass. Some of the quartz shows undulatory extinction, but otherwise the rock gives no evidence of having been subject to pressure. Scattered through the ground-mass are irregularly outlined green areas composed of chlorite and epidote. What the original ferromagnesian constituent of the rock was is now impossible to determine. A few small acute rhombs of sphene are also present. The rock is properly a microgranite. Rock No. 416, from the edge of this dyke, presents the same appearance as that just described, except that the ground-mass is of some finer grain and the feldspar is mostly in fragments.

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*This locality has been already fully described in the 15th (1886) Annual Report, pp. 345-347.

The shores of this lake seem to be made entirely of greenstone, cut in a few places by quartz porphyry dykes. The greenstone is very massive and in no place where examined shows any evidence of lamination or schistosity. It is well represented by No. 412, from the portage south of the lake, and by No. 418, from the north shore on the line between secs. 16 and 21.

From this lake there is a trail running north on the line between secs. 15 and 16 to a small lake lying in the N. W. ¼ of sec. 15 and the N. E. ¼ of sec. 16. No rock is *in situ* along this trail, but at the shore of the latter lake the greenstone is in place. The shores of the lake, as far as could be seen from the meander corner, were lined with rock which had all the appearance of greenstone. On this trail and a few yards south of the lake is a low hill, the north side of which shows many angular fragments of rock. This rock is made up of alternating bands of compact black slate and bands of almost pure magnetite. These bands vary from one-eighth of an inch to an inch in thickness. They are very regular, and on the whole the rock is very similar to some Kewatin ore described from Ottertrack lake.* The fragments of this rock were of all sizes up to those three feet in diameter, and while no pieces were exactly *in situ*, still there can be no doubt but that the rock is *in situ* just below these fragments. No. 419 represents this rock.

From the north shore of the Kawishiwi river, in the N. E. ¼ of S. W. ¼ sec. 24, a portage runs northwesterly to the southeast corner of Triangle lake. This lake lies in secs. 13, 14, 23 and 24, T. 63-10. Just north of the river the portage crosses a low ridge of gneissic syenite, and a short distance beyond is a ridge of the graywacke-like rock. This latter is shown by Nos. 453, 454 and 455. Just east of the portage this ridge is seen to better advantage; here the strike is N. 60° E., and the dip vertical. Fifty feet north of this ridge massive greenstone (No. 456) is seen. The two rocks were traced within thirty feet of each other, but the junction was covered by soil. Beyond this more greenstone ridges are seen on the portage; usually the rock is massive in appearance, but it sometimes shows an indistinct schistose structure which stands vertical and strikes about northeast. About half way over the portage is a ridge of greenish, finely laminated rock, represented by No. 457. The lamination is very distinctly seen on weathered surfaces, and in places the rock is decidedly slaty. The strike is N. 65° E., and the dip vertical. This rock seems to be a facies of the greenstone. Beyond this rock greenstone is seen in several places on the trail before reaching Triangle lake. Several outcrops on the east shore of this lake were examined, but the rock was all greenstone.

From the northeast corner of Triangle lake a portage of a few yards leads to Northwest lake, which lies in secs. 11, 12, 13 and 14, T. 63-10, and secs. 7 and 18, T. 63-9. On the south side of a small island, in the N. E. ¼ of N. W. ¼ sec. 13 (Northwest lake), is a low outcrop of altered quartz porphyry (No. 458). This rock has the ground-mass almost entirely changed to a sericitic condition, but it still contains many porphyritic quartzes and large pinkish feldspars. Some of the feldspars are an inch long; they can be read-

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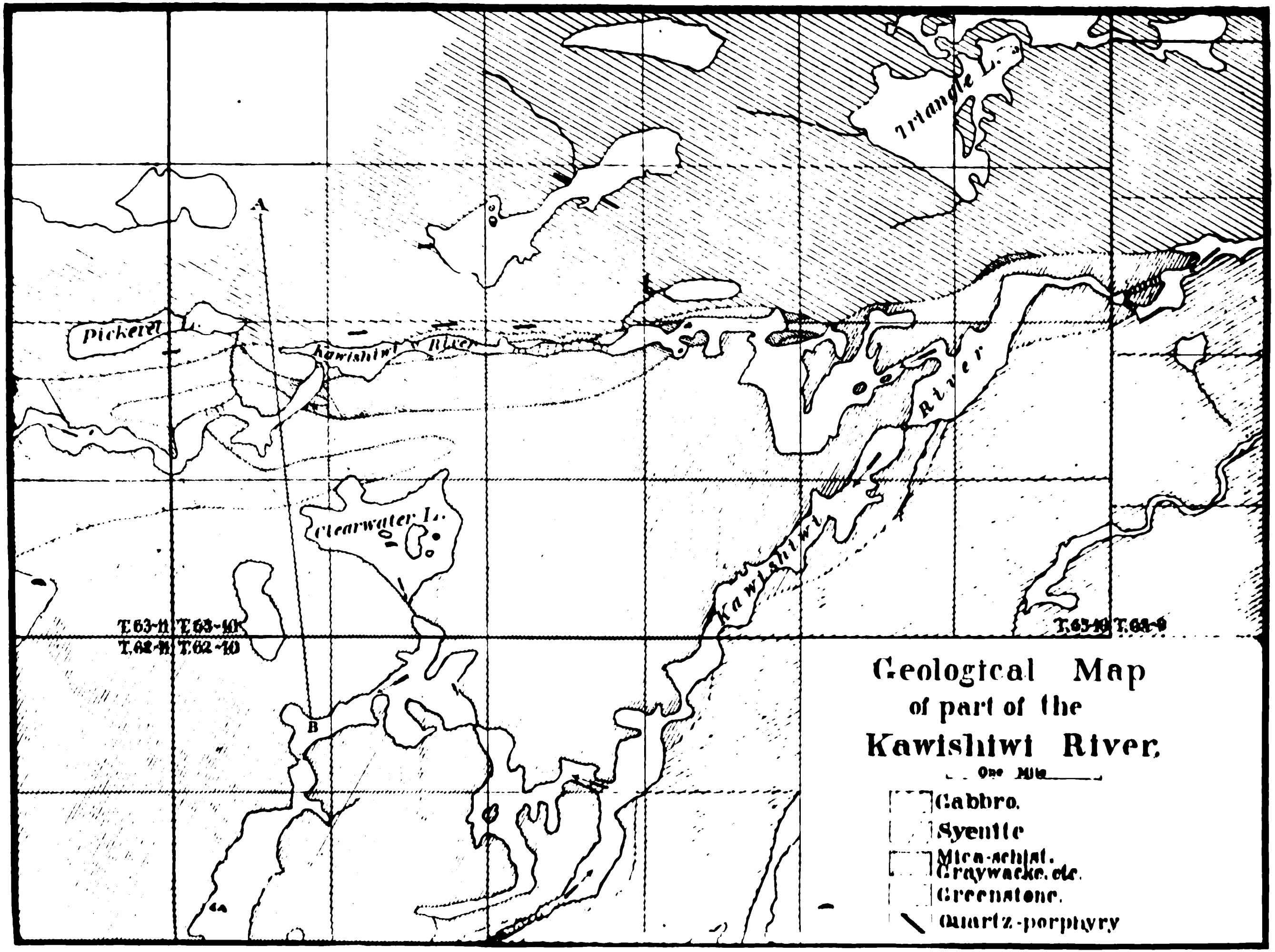
*17th (1888) Annual Report, pp. 112-113.



Geological Map of part of the Kawishiwi River.

ily broken out of the ground-mass, and they show complete crystal outlines. The sericitic ground-mass gives a rough schistose structure to the rock; the strike of this is N. 60° E., and the dip about vertical. The south shore of this lake was examined in several places and the greenstone was the only rock seen; this extends to the extreme eastern end of the lake in the N. E. ¼ of sec. 18, T. 63-9. On the north side of the lake, in the N. E. ¼ of N. E. ¼ sec. 13, T. 63-10, the greenstone has a peculiarly mottled appearance. This is shown by No. 459. It is due to numerous black blotches, apparently of hornblende.

### *Geological map of part of the Kawishiwi river.*

The distribution of the different rock masses in that part of the Kawishiwi river, described in the foregoing field notes, is shown on the accompanying map. Five distinct rock types are present, the characters and relations of which have already been briefly given. The gabbro is the most recent; it covers parts of the older rocks and is very extensively developed just to the south of the area of this map. The syenite is older than the gabbro, and is younger than the greenstone and mica-schist, both of which it cuts in a truly irruptive manner. The mica-schists, graywackes, etc., stand vertical and have a general E. N.-E. strike; they belong to what has been mapped as the Vermilion series, but there seems to be good reason for putting all of this type of rocks, in the area of this map, into the Keewatin. The greenstone is presumably of Keewatin age and is probably younger than the mica-schists, graywackes, etc. Quartz porphyry dykes are found cutting the greenstone in several places, but they have not yet been seen in the other rocks in this immediate vicinity.

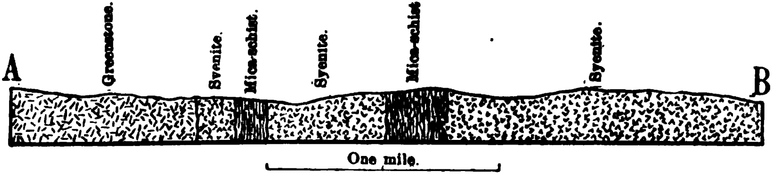


Fig. 3. Section along the line A B, of the geological map of part of the Kawishiwi river.

### B. SNOWBANK LAKE AREA.

The outlines of the granite on this lake were traced much less minutely than those of any other of the areas visited. In fact but a short time was spent in this vicinity, and the only things to which much attention was given were the nature of the granite and its relations to the surrounding rocks.

### *Portage from the Kawishiwi river to Snowbank lake.*

This portage starts from the river in the N. E. ¼ of N. W. ¼ sec. 15, crosses the S. E. corner of sec. 10 and reaches Snowbank lake at its southwestern corner in the S. E. ¼ of N, E. ¼ sec. 11; all in T. 63–9. No rock but the ordinary coarse grained gabbro was seen until after reaching the S. W. ¼ of sec. 11.* About one third of a mile east of the line between secs. 10 and 11 is a low ridge of coarse pinkish syenite (No. 474). A short distance beyond this is an outcrop of fine grained red syenite (No. 475), and farther on, just to the right of and on the portage, is a coarse pink syenite (No, 476) much resembling No. 474. A little farther is a dark colored rather fine grained diorite (No. 477), and just beyond this is another still finer grained diorite, which continues for a short distance, where it is cut by veins of a fine grained gray to reddish syenite (No. 478); at this latter place the finer diorite is represented by No. 479. On the north side of the same ridge in which the last two rocks occur a gray porphyritic syenite (No. 480) is seen. The relation of this to the other rocks could not be determined. Farther on and a short distance to the left of the trail is a low ridge of this same gray porphyritic syenite, here represented by No. 481. There are thus seen on this portage several apparently distinct kinds of syenite, but the relations between them were not ascertained, as there were but few outcrops and in no exposure did two of these syenites occur together.

### *Snowbank lake.*

On the west shore, in the N. ½ of N. E. ¼ sec. 11, T. 63–9, a fine grained syenite (No. 482) in seen; this is quite similar in appearance to Nos. 480 and 481. Farther north syenite is again seen on the shore; here it is coarser grained and not at all like No. 482. This coarser grained syenite extends along the west shore into the northwest corner of the bay in the S. ½ of S. E. ¼ sec. 2, T. 63–9. Here it is represented by Nos. 483 and 484; the former is a dark red syenite of medium grain, and the latter is of lighter color, contains less hornblende and is the facies of the rock that is most common at this locality. Just off the point, which is in the N. W. ¼ of S. E. ¼ sec. 2, T. 63–9, is a small island made of a coarser facies of the same syenite (No. 485). This is cut by veins, of all sizes up to three feet across, of a dull reddish rather coarse grained syenite (No. 486) made up almost entirely of feldspar; the other constituent is in small amount and seems to be epidote. The point crossed by the line between secs. 35 and 36, T. 64–9, is composed of dark diorite of medium grain (No. 487); this appears in the form of a dyke, 100 feet or more in width. It runs about north and south. The syenite was seen just east of this point and also along the shore west of it; here the syenite is quite coarse grained and contains much biotite (No. 488). The point on the south shore, in the S. E. ¼ of N. W. ¼ sec. 35, T. 64–9, shows syenite of a rather fine grain (No. 489).

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*For descriptions of the gabbro and associated rocks on this portage, in secs. 10 and 15, see the 17th (1888) Annual Report, p. 120.

The bay which runs south along the line between secs. 34 and 35, T. 64–9, shows no outcrops along its shores. And on going west a short distance, near the township line, no rock was seen *in situ.*

On the west shore, in the N. E. ¼ of N. E. ¼ sec. 34, T. 64–9, a shore distance north of the portage which runs to Flash lake, is a large bluff of fine grained diabase. Farther north on the west shore of the narrow bay in the S. E. ¼ of S. E. ¼ sec. 27, T. 64–9, the fine grained greenish diabase, here represented by No. 489A, is cut by an irregular dyke of reddish porphyry (No. 490). This dyke is from two to five feet wide and was traced for at least thirty feet. Another small mass of this same rock was seen near by, but it was exposed only in one place. This porphyry (No. 490) has a reddish to purplish aphanitic ground-mass, in which are porphyritic crystals of red feldspar and small areas of chlorite. Under the microscope the ground-mass is seen to be microgranitic in structure and apparently composed of quartz and feldspar. The feldspar phenocrysts are more or less altered and the majority of them show polysynthetic twinning. Irregular areas of chlorite occur in the ground-mass, but nothing is left to show what was the mineral that originally occupied these areas. A few small apatite prisms are present, and scattered through the whole rock are minute green flakes of chlorite. The rock is probably a syenite porphyry.

No rock except that above described is seen on the shores of this narrow bay north of the south line of sec. 27, T. 64–9. But where this line crosses the east shore of the bay there is a low ridge which shows angular fragments of fine grained greenish diabase similar to No. 489A. No rock is seen in place along the southwest shore of the promontory, on which are the corners of secs. 26, 27, 34 and 35, T. 64–9, but many angular fragments of the fine grained diabase occur at the water's edge. On the sharp point, at the southern end of this promontory, angular fragments of the diabase and of porphyry, similar to No. 490, are seen. Along the shore just east of this point are angular fragments of granite, and a little further north this granite occurs *in situ*. Several outcrops of the same are seen along the shore before coming to the line between secs. 26 and 35, T. 64-9. At this place No. 491 was collected; this well represents the granite from the east shore of this promontory. It is a granite of medium grain, reddish color and compact texture; the feldspar varies from reddish to white, and the hornblende is in small grains and does not make up more than one-fifth of the whole rock. Quartz is present in small amount. Under the microscope this rock (No. 491) is seen to be a distinct hornblende granite. Quartz is present in larger quantity than is noticed in the hand specimen. The feldspar is more or less cloudy and many of the grains show a microcline structure and have a wavy extinction, as have also some of the quartz grains. The hornblende is quite fresh and of the ordinary green variety. A few scales of brown biotite are present, and also some green chlorite, which appears as an alteration product from the biotite. Bright brownish sphene is seen in considerable amount. Ilmenite, or magnetite, and apatite prisms are also present. This is the first true granite seen on this lake, but there is no reason to suppose that it is distinct from the syenite found elsewhere on the lake; in fact, everything seems to indicate that it is but an acid facies of the syenite. About 150 feet south of the above mentioned section line is a low outcrop of mica-schist, much twisted and bent. This schist is represented by No. 492, which is a fine grained compact mica-schist, and by No. 493, which is coarser and more properly gneiss. A few feet north of this the same schist is seen again; here it is cut by many granite dykes which vary from six inches to three feet in width. This granite is part of the same as that mentioned above (No. 491). The dykes in general run along between the cleavage planes of the schist, but some were seen cutting across these planes. The schist here is sometimes much changed near the contact with the granite, as is shown by Nos. 494 and 495, which are distinctly gneisses; the latter is decidedly reddish in color. There is no gradation from the schist or the gneissic parts of it into the granite; the contact between the two rocks is sharp and distinct, as is seen in No. 496. This specimen shows the two rocks, granite and schist, in contact; it was taken from the edge of a dyke one foot in width. The schist at this place is so twisted that no general strike can be made out. In places the granite includes pieces of the schist. A few yards north of this section line and back about 100 feet from the shore is quite a large exposure of the schists. These are bent some, but there is a decidedly general trend to the strike; it is N. 35° E., and the dip is almost vertical. Just beyond (north) this exposure of schist, and in the strike of part of it, is another outcrop of the granite similar to No. 491. On one of these outcrops there is a small amount, one by three feet in area and one foot thick, of purple porphyry; the contact with the granite was sharp and a distinct line, and there was nothing to show whether this rock was part of a dyke or an inclusion in the granite. This porphyry is represented by No. 497; it has a fresh unaltered appearance and seems exactly similar to that already described under No. 490, except that that the latter is not very fresh. A short distance north of the section line (between secs. 26 and 35) and about an eighth of a mile from the shore is a small island composed entirely of granite (No. 498). This island is directly in the strike of the last mentioned outcrop of schist. The granite of the island (No. 498) is of rather fine grain and holds a considerable amount of quartz, but is the same granite as that described above (No. 491). On the northeastern end of this island the granite is jointed in a very noticeable manner; the joints split the rock into parallel beds that stand vertical and strike N. 70° E.

On the south shore of the little bay, in the S. E. ¼ of S. W. ¼ sec. 26, T. 61-9, the schist is seen in many places, and the granite is seen in contact with it at a few points. The schist here is well represented by the specimens collected near the south line of this section; and where the schist is in contact with the granite it takes on the same characters as seen in Nos. 494 and 495. In one place a small tongue of the granite was seen running across the strike of the schists, as shown in the accompanying illustration (Fig. 4). Along the shore of this bay the schist is twisted so much that no general direction of strike is noticeable.

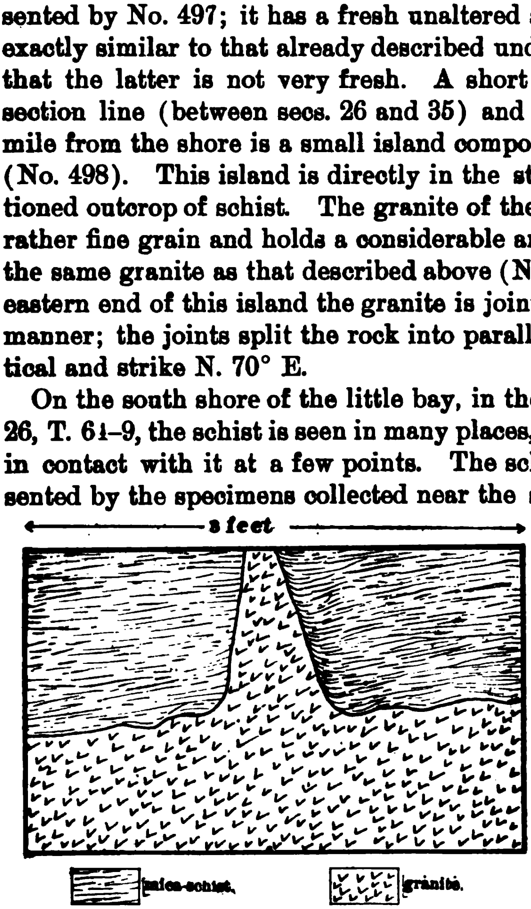

Fig. 4. Contact of granite and mica-schist; S. E. ¼ S. W. ¼ sec. 26, T. 61-9, west shore of Snowbank lake.

On the south side of this bay, near its western end and down at the water's edge, the schist is cut by a small dyke. This dyke is four feet wide, but was not exposed for over seven feet; the walls are parallel, stand vertical and strike N. 50° E. The line between the dyke and the schist is very sharp. The dyke rock is a purple porphyritic rock similar to that already described under Nos. 490 and 497; it differs from these, however, in having distinct glistening biotite scales scattered through the ground-mass. The rock may be provisionally called a syenite porphyry. No. 500 is this rock from the centre of the dyke, and No. 501 is the same from one edge of the dyke. The schist at this place has a dip of 60° towards the east, and a strike almost due north and south. The schist from near the dyke is represented by No. 499; this is a rather fine grained gray biotitic gneiss. In section this gneiss (No. 499) is seen to be a holocrystalline aggregate of interlocking grains of quartz, feldspar, biotite and hornblende. Many of the grains are elongated somewhat in one direction, this is especially true of the biotite, and there seems to be a tendency for grains of the same size and of the same minerals to be collected somewhat in irregular parallel lines. This causes a decidedly schistose structure to pervade the rock. None of the mineral grains show any evidence of a clastic origin. The quartz is clear and limpid and is in larger grains than the other minerals; it makes up about half of the rock. The feldspar, while cloudy in small areas, is usually clear; most of it is orthoclase, but some good sized plagioclases are present. The biotite is brown and fresh; it, more than any of the other minerals, is chiefly confined to certain irregular lines. The biotite is in small scales, most all of which are arranged with their long axes in the direction of the schistosity of the rock. Hornblende of the ordinary green variety is present in a few irregular areas; it appears very fresh. All the minerals of the rock present a decidedly fresh and unaltered appearance.

The granite occurs at the west end of the little bay, in the S. E ¼ of S. W. ¼ sec. 26, T 64-9, and also along the shore for a short distance north of this place. The point in the N. E. ¼ of S. W. ¼ of the same section consists of a high ridge of green schists. These shists are hard and of a general green color; they seem to consist of mica, chlorite and silicious matter very closely intermingled. The rock has a fine lamination due to rapid alterations in the arrangement of the constituents, thus producing laminæ of different hardness and composition; this lamination is very clearly shown on weathered surfaces; it is parallel to the schistose structure of the rock. In places the schist is conglomeritic, containing pebbles of all sizes, up to a foot in length, elongated in the direction of the strike. The strike is N. 20° E. and the dip is 75° to 80° towards the east. At the east edge of this ridge the schists are in contact with the granite. The contact line is sharp and runs parallel with the strike of the schists, but the granite sends off many small dykes into the schists across the strike. No. 502 represents these green schists. No. 502A is part of one of the pebbles; it is a gray gneiss. No. 503 is the granite from one of the dykes four inches wide; this is a fine grained, reddish, hornblende granite.

The green schists extend from the point part way along the southeastern shore of the bay, in the N. W. ¼ of S. W. ¼ sec. 26, T. 64–9, but on this side of the bay, near its end, is a dark, compact, aphanitic rock holding white feldspar phenocrysts. This is probably a porphyrite (No. 504). It is massive at the shore, but on going back a few rods from the shore it becomes schistose, as is shown by No. 505. This porphyrite was traced eastward until it came within fifty feet of the green schists, but soil covered the contact. The porphyrite and the green schist at this place each had their distinct characters. The schistose structure of the porphyrite is parallel with that of the green schist. In one place the prophyrite is cut by a dyke of a fine grained syenite (No. 506). This dyke is four feet wide, stands vertical and runs east and west.

On the west side of this bay the green schists appear again and seem to get more massive on going northward, but the shore here was not carefully examined. In the S. W. ¼ of N. E. ¼ sec. 26 massive greenstone, into which the green schist seems to grade, is cut by a dyke of syenite porphyry, similar to No. 500. On the shore just north and east of this the greenstone and syenite are seen together. The greenstone here is quite massive in appearance and the contact with the syenite was seen in only one place; here it was a decidedly sharp line and two small pieces of the greenstone were seen in the syenite. At this place the syenite also cuts a gray diorite blotched with hornblende (No. 507); the relation of this diorite to the greenstone could not be determined. The syenite is itself cut by a fine grained greenstone (No. 508), in a dyke which varies from eight inches to two feet in width; this was traced for thirty feet. It may be that this is not a true dyke, but a part of the greenstone surrounded by syenite as it is decidedly similar to the greenstone and can not be distinguished from it in hand specimen. The syenite is here represented by No. 509, which is a reddish rock of rather medium grain. The greenstone is shown by No. 510.

Just north of this mica-schist is seen cut in every direction by dykes of the syenite, which vary in width from two inches to thirty feet. The mica-schist is shown by No. 511. Farther north there is a large mass of the schist exposed; here it varies from a mica-schist like No. 511, to a green schist (No. 512), which is very similar to the green schists described above. The strike here is N. 20°

E., and the dip is about vertical. These schists extend along the shore up to and beyond the line between secs. 23 and 26, T. 64-9. Sometimes they are cut by dykes of hornblende granite represented by No. 513. Near this section line the schists become very hard and compact; No. 514 from this place is a very siliceous, fine grained graywacke. Here the strike is N. 25° E., and the dip is about vertical. On a ragged bluff just north of this section line the schists are much crumpled and twisted and they become hard and very silicious. No. 515 fairly represents the schists at this place. The schists continue along the lake shore in secs. 23 and 24, T. 64-9. In places they are massive in appearance, but usually a lamination can be seen on their weathered surfaces; this, however, is much twisted in every direction, but there is a general northeasterly strike and a vertical dip. The schists in these two sections are well represented by Nos. 515, 516 and 517.

Where the line between ranges 8 and 9 crosses the north shore granite occurs, It is represented by No. 518, which is very similar to the granite and syenite found elsewhere on the lake. The granite here cuts the schists in dykes running in every direction. Some of these dykes are apparently a hundred feet wide, while others are not more than a foot. The contact between the two rocks is a very sharp line, as is shown by specimen No. 519, which was broken from the edge of a dyke eight feet wide. The schists at this place are represented by No. 520, taken within two feet of the granite; it is a fine, hard, silicious mica-schist. Here there is seen a small amount of a rather fine grained dark syenite (No. 521); this is distinct from the granite and is cut by it. The relation of this rock to the schists could not be determined. Just east of the range line the schists are seen in large amount. Here the strike is N. 70° E., and the dip southward from 70° to 80°. The schists, sometimes cut by the granite, extend along the shore to the bay in the S. W. ¼ of N. E. ¼ sec. 19, T. 64-8. On the west side of this bay the schists are graywacke schists. The strike is almost east and west and the dip varies from 65° to 80° towards the south. These schists are also seen at the north end and on the east side of this bay.

There is a small island in the N. E. ¼ of S. W. ¼ sec. 19, T. 64-8, on the eastern end of which is a large exposure of gray to reddish syenite of medium grain (No. 522). Mr. Wood went over most of this island and found it to be made of the same syenite.

Syenite from the shore in the N. W. ¼ of S. W. ¼ sec. 29, T. 64-8 is of medium grain and light gray color. Small areas of the feldspar have a peculiar yellow stain, No. 523.

Several outcrops on the east shore of the large island, which lies in secs. 30 and 31, T, 64–8, and secs. 25 and 36, T. 64–9, were examined. They are all composed of rather coarse syenite which holds large quantities of biotite. No. 524. Coarse syenite similar to this occurs on the east shore on the line between sec. 36, T. 64–8, and sec. 1, T. 63–9.

At the southwest end of the island that is crossed by the line between secs. 30 and 31, T. 64–8, there is an outcrop of fine grained biotite gneiss (No. 525).

### *Round lake.*

This lake lies mostly in sec. 6. T. 63–8. The portage from Snowbank lake to Round lake is in the N. E. ¼ of sec. 1, T. 63–9. At the Snowbank lake end of this portage coarse syenite similar to No. 524 occurs. About half way over the portage a finer grained, reddish syenite (No. 526) is seen. But at the Round lake end of the portage is coarser syenite similar to No. 524. On the north side of the lake just west of the east line of sec. 1, T. 64–9, is a low outcrop of hardened mica-schist, cut by fine syenite veins. No. 527 shows the mica-schist and a small granite vein. The lamination of the schist is here twisted and bent, but there seems to be a general strike, No. 65° E.; however, this strike is not very pronounced. Further west on the shore are many angular fragments of syenite similar to No. 526. On the shore in the N. E. ¼ of S. E. ¼ sec. 1, T. 63–9, is an outcrop of the schist which is here more like gneiss (No. 528). In contact with this and separated from it by a sharp line is a small piece of syenite which held a small lenticular piece of the schist, or gneiss. Back from the shore is a small hill much covered by soil, but still exposing several angular fragments of rock that are undoubtedly *in situ* just below. Here a gneissic rock (No. 529) and red syenite (No. 530) were seen, and in one place they were in sharp contact; in other places they seem to grade into each other through No. 531 and 532; but nothing definite as to the relation of the syenite and gneiss could be seen here. Syenite again occurs on the shore a little south of this and is seen in angular blocks along the southwestern shore of the lake. On the shore in the N. E. ¼ of N. W. ¼ sec. 7, T. 63–8, is a low outcrop of a rather fine grained, brownish syenite (?) (No. 533). On the small stream that comes into the lake in this one-sixteenth section and about 100 yards from the shore is an exposure of coarse grained syenite. No other outcrops are seen along this stream until about a quarter of a mile south of the lake; here the ordinary coarse grained gabbro of the region occurs.

A low outcrop of mica-schist similar to No. 527 occurs on the north side of the lake in the N. W. ¼ of sec. 6, T. 63–8. A little further east syenite similar to No. 526 is seen. In the N. W. ¼ of N. E. ¼ of the same section the schists again appears. Here there is a decided strike of N. 70° E.; the dip is about vertical. The schists vary from mica-schist to graywacke-schist to quartz-schist. They are seen in several places along the northeast shore of the lake and also on the east shore. In some places the schists are cut by red syenite veins or dykes (No. 534). The most southern exposure of schists seen was on the east shore of the lake on the south line of sec. 6.

In the N. W. ¼ of N. E. ¼ sec. 7, T. 63–8, just south of the lake is a northerly facing gabbro bluff and at the base of it syenite is seen. The gabbro is the usual coarse grained gabbro common to this region. The position of the two rocks would indicate that the gabbro was the younger and overlay the syenite, but no positive proof of this was to be seen, as soil covers the junction of the two rocks. In the syenite a small dyke, ten inches wide, of a fine grained gabbro (?) occurs; this was exposed for only three feet in length. The contact with the syenite was a sharp line as is shown by No. 535. The dyke rock is represented by No. 536. The gabbro proper retained its coarse grained character as near to the syenite as it was exposed. No. 537 is the gabbro in the exposure nearest the syenite.

### *Disappointment lake.*

This is also called Cheadle's lake. It is an irregular lake lying in secs. 3 and 4 of T. 63–8 and secs. 27, 28, 32, 33 and 34 of T. 64–8. Mica-schist occurs on the portage from Round lake. At the east end of the portage in the N. W. ¼ of S. W. ¼ sec. 3 is a low outcrop of schists, almost argillaceous in places. The strike here is N. 15° E., and the dip is vertical. The western shore of the lake has many large exposures of conglomeritic mica-schist cut in many places by fine red syenite. This syenite occurs in some amount on the portage to Snowbank lake (S. ½ of S. W. ¼ sec. 32) and is here seen cutting a peculiar gray rock. This gray rock (No. 539) seems to be a holocrystalline aggregate of gray feldspar grains among which are scattered hornblende prisms. In one place this gray feldspathic rock held many pieces of a darker rock, apparently a diorite; this is well shown by the specimen collected (No. 539). These pieces of diorite are of irregular shapes and all sizes up to those ten inches in diameter; none of them are lenticular in shape and they do not present the rounded outlines of pebbles. This gray rock lies

to the north of the portage and is between two ridges of mica-schist, but was not seen in contact with the schist. No. 539 is the fine red syenite which cuts the gray rock.

### *North of Disappointment lake*

Two small lakes, one lying in the N. ½ of sec. 27 and the other in the S. E. ¼ of sec. 21, T. 64–8, were passed through. The rock on the shores of both of these small lakes was massive in appearance and varied from a very siliceous graywacke to a hard, fine grained green rock, resembling the ordinary greenstone of the region. Most of the shore line of the former of these lakes was examined, but no rock was seen excepting that just spoken of.

## C. KEKEQUABIC LAKE AREA.

### *South of Kekequabic lake, in secs. 11 and 14, T. 64–7.*

On the portage, in the N. E. ¼ of N. W. ¼ sec. 11, is a ridge of soft dark greenish rock, which is composed largely of biotite (No. 540). An irregular lake, lying in the centre of sec. 11, has been called River lake. Its shores are made of a fine grained gabbro-like rock. This varies from No. 541, a rather coarse facies from the west end of the lake, to No. 542, of finer grain from the portage in the N. E. ¼ of S. E. ¼ sec. 11. Most of the rock, however, is finer grained than No. 541. In places this rock has small veins or streaks running through it; these are composed mostly of biotite. At times they are quite close together, as shown by No. 543, and again very few of them are seen. No general direction for these black streaks could be seen. On the north side of the central western arm of this lake the gabbro-like rock held many angular and twisted fragments of a reddish syenite similar to that found on Kekequabic lake, and also of a fine grained greenstone (No. 544). These fragments are of all sizes up to those a foot in diameter; they are very irregular in outline, none of them are rounded, and they are often much twisted and stretched. No. 545 shows some of the fragments in the enclosing rock.

A few rods back from the shore, on the south side of River lake and near the entrance to the southern of the western arms of the lake, is a westerly facing bluff made up mostly of the fine gabbro-like rock. In the face of the bluff is a small area of syenite (No. 546). This is rather fine grained and is composed of pinkish feldspar, hornblende and some biotite. The syenite was seen within six feet of the other rock, but at this place neither of them showed any change from their normal condition.

A low outcrop of mica-schist similar to No. 527 occurs on the north side of the lake in the N. W. ¼ of sec. 6, T. 63–8. A little further east syenite similar to No. 526 is seen. In the N. W. ¼ of N. E. ¼ of the same section the schists again appears. Here there is a decided strike of N. 70° E.; the dip is about vertical. The schists vary from mica-schist to graywacke-schist to quartz-schist. They are seen in several places along the northeast shore of the lake and also on the east shore. In some places the schists are cut by red syenite veins or dykes (No. 534). The most southern exposure of schists seen was on the east shore of the lake on the south line of sec. 6.

In the N. W. ¼ of N. E. ¼ sec. 7, T. 63–8, just south of the lake is a northerly facing gabbro bluff and at the base of it syenite is seen. The gabbro is the usual coarse grained gabbro common to this region. The position of the two rocks would indicate that the gabbro was the younger and overlay the syenite, but no positive proof of this was to be seen, as soil covers the junction of the two rocks. In the syenite a small dyke, ten inches wide, of a fine grained gabbro (?) occurs; this was exposed for only three feet in length. The contact with the syenite was a sharp line as is shown by No. 535. The dyke rock is represented by No. 536. The gabbro proper retained its coarse grained character as near to the syenite as it was exposed. No. 537 is the gabbro in the exposure nearest the syenite.

### *Disappointment lake.*

This is also called Cheadle's lake. It is an irregular lake lying in secs. 3 and 4 of T. 63–8 and secs. 27, 28, 32, 33 and 34 of T. 64–8. Mica-schist occurs on the portage from Round lake. At the east end of the portage in the N. W. ¼ of S. W. ¼ sec. 3 is a low outcrop of schists, almost argillaceous in places. The strike here is N. 15° E., and the dip is vertical. The western shore of the lake has many large exposures of conglomeritic mica-schist cut in many places by fine red syenite. This syenite occurs in some amount on the portage to Snowbank lake (S. ½ of S. W. ¼ sec. 32) and is here seen cutting a peculiar gray rock. This gray rock (No. 539) seems to be a holocrystalline aggregate of gray feldspar grains among which are scattered hornblende prisms. In one place this gray feldspathic rock held many pieces of a darker rock, apparently a diorite; this is well shown by the specimen collected (No. 539). These pieces of diorite are of irregular shapes and all sizes up to those ten inches in diameter; none of them are lenticular in shape and they do not present the rounded outlines of pebbles. This gray rock lies

to the north of the portage and is between two ridges of mica-schist, but was not seen in contact with the schist. No. 539 is the fine red syenite which cuts the gray rock.

### *North of Disappointment lake*

Two small lakes, one lying in the N. ½ of sec. 27 and the other in the S. E. ¼ of sec. 21, T. 64–8, were passed through. The rock on the shores of both of these small lakes was massive in appearance and varied from a very siliceous graywacke to a hard, fine grained green rock, resembling the ordinary greenstone of the region. Most of the shore line of the former of these lakes was examined, but no rock was seen excepting that just spoken of.

## C. KEKEQUABIC LAKE AREA.

### *South of Kekequabic lake, in secs. 11 and 14, T. 64–7.*

On the portage, in the N. E. ¼ of N. W. ¼ sec. 11, is a ridge of soft dark greenish rock, which is composed largely of biotite (No. 540). An irregular lake, lying in the centre of sec. 11, has been called River lake. Its shores are made of a fine grained gabbro-like rock. This varies from No. 541, a rather coarse facies from the west end of the lake, to No. 542, of finer grain from the portage in the N. E. ¼ of S. E. ¼ sec. 11. Most of the rock, however, is finer grained than No. 541. In places this rock has small veins or streaks running through it; these are composed mostly of biotite. At times they are quite close together, as shown by No. 543, and again very few of them are seen. No general direction for these black streaks could be seen. On the north side of the central western arm of this lake the gabbro-like rock held many angular and twisted fragments of a reddish syenite similar to that found on Kekequabic lake, and also of a fine grained greenstone (No. 544). These fragments are of all sizes up to those a foot in diameter; they are very irregular in outline, none of them are rounded, and they are often much twisted and stretched. No. 545 shows some of the fragments in the enclosing rock.

A few rods back from the shore, on the south side of River lake and near the entrance to the southern of the western arms of the lake, is a westerly facing bluff made up mostly of the fine gabbro-like rock. In the face of the bluff is a small area of syenite (No. 546). This is rather fine grained and is composed of pinkish feldspar, hornblende and some biotite. The syenite was seen within six feet of the other rock, but at this place neither of them showed any change from their normal condition.

A low outcrop of mica-schist similar to No. 527 occurs on the north side of the lake in the N. W. ¼ of sec. 6, T. 63–8. A little further east syenite similar to No. 526 is seen. In the N. W. ¼ of N. E. ¼ of the same section the schists again appears. Here there is a decided strike of N. 70° E.; the dip is about vertical. The schists vary from mica-schist to graywacke-schist to quartz-schist. They are seen in several places along the northeast shore of the lake and also on the east shore. In some places the schists are cut by red syenite veins or dykes (No. 534). The most southern exposure of schists seen was on the east shore of the lake on the south line of sec. 6.

In the N. W. ¼ of N. E. ¼ sec. 7, T. 63–8, just south of the lake is a northerly facing gabbro bluff and at the base of it syenite is seen. The gabbro is the usual coarse grained gabbro common to this region. The position of the two rocks would indicate that the gabbro was the younger and overlay the syenite, but no positive proof of this was to be seen, as soil covers the junction of the two rocks. In the syenite a small dyke, ten inches wide, of a fine grained gabbro (?) occurs; this was exposed for only three feet in length. The contact with the syenite was a sharp line as is shown by No. 535. The dyke rock is represented by No. 536. The gabbro proper retained its coarse grained character as near to the syenite as it was exposed. No. 537 is the gabbro in the exposure nearest the syenite.

### *Disappointment lake.*

This is also called Cheadle's lake. It is an irregular lake lying in secs. 3 and 4 of T. 63–8 and secs. 27, 28, 32, 33 and 34 of T. 64–8. Mica-schist occurs on the portage from Round lake. At the east end of the portage in the N. W. ¼ of S. W. ¼ sec. 3 is a low outcrop of schists, almost argillaceous in places. The strike here is N. 15° E., and the dip is vertical. The western shore of the lake has many large exposures of conglomeritic mica-schist cut in many places by fine red syenite. This syenite occurs in some amount on the portage to Snowbank lake (S. ½ of S. W. ¼ sec. 32) and is here seen cutting a peculiar gray rock. This gray rock (No. 539) seems to be a holocrystalline aggregate of gray feldspar grains among which are scattered hornblende prisms. In one place this gray feldspathic rock held many pieces of a darker rock, apparently a diorite; this is well shown by the specimen collected (No. 539). These pieces of diorite are of irregular shapes and all sizes up to those ten inches in diameter; none of them are lenticular in shape and they do not present the rounded outlines of pebbles. This gray rock lies

to the north of the portage and is between two ridges of mica-schist, but was not seen in contact with the schist. No. 539 is the fine red syenite which cuts the gray rock.

### *North of Disappointment lake*

Two small lakes, one lying in the N. ½ of sec. 27 and the other in the S. E. ¼ of sec. 21, T. 64–8, were passed through. The rock on the shores of both of these small lakes was massive in appearance and varied from a very siliceous graywacke to a hard, fine grained green rock, resembling the ordinary greenstone of the region. Most of the shore line of the former of these lakes was examined, but no rock was seen excepting that just spoken of.

## C. KEKEQUABIC LAKE AREA.

### *South of Kekequabic lake, in secs. 11 and 14, T. 64–7.*

On the portage, in the N. E. ¼ of N. W. ¼ sec. 11, is a ridge of soft dark greenish rock, which is composed largely of biotite (No. 540). An irregular lake, lying in the centre of sec. 11, has been called River lake. Its shores are made of a fine grained gabbro-like rock. This varies from No. 541, a rather coarse facies from the west end of the lake, to No. 542, of finer grain from the portage in the N. E. ¼ of S. E. ¼ sec. 11. Most of the rock, however, is finer grained than No. 541. In places this rock has small veins or streaks running through it; these are composed mostly of biotite. At times they are quite close together, as shown by No. 543, and again very few of them are seen. No general direction for these black streaks could be seen. On the north side of the central western arm of this lake the gabbro-like rock held many angular and twisted fragments of a reddish syenite similar to that found on Kekequabic lake, and also of a fine grained greenstone (No. 544). These fragments are of all sizes up to those a foot in diameter; they are very irregular in outline, none of them are rounded, and they are often much twisted and stretched. No. 545 shows some of the fragments in the enclosing rock.

A few rods back from the shore, on the south side of River lake and near the entrance to the southern of the western arms of the lake, is a westerly facing bluff made up mostly of the fine gabbro-like rock. In the face of the bluff is a small area of syenite (No. 546). This is rather fine grained and is composed of pinkish feldspar, hornblende and some biotite. The syenite was seen within six feet of the other rock, but at this place neither of them showed any change from their normal condition.

A low outcrop of mica-schist similar to No. 527 occurs on the north side of the lake in the N. W. ¼ of sec. 6, T. 63–8. A little further east syenite similar to No. 526 is seen. In the N. W. ¼ of N. E. ¼ of the same section the schists again appears. Here there is a decided strike of N. 70° E.; the dip is about vertical. The schists vary from mica-schist to graywacke-schist to quartz-schist. They are seen in several places along the northeast shore of the lake and also on the east shore. In some places the schists are cut by red syenite veins or dykes (No. 534). The most southern exposure of schists seen was on the east shore of the lake on the south line of sec. 6.

In the N. W. ¼ of N. E. ¼ sec. 7, T. 63–8, just south of the lake is a northerly facing gabbro bluff and at the base of it syenite is seen. The gabbro is the usual coarse grained gabbro common to this region. The position of the two rocks would indicate that the gabbro was the younger and overlay the syenite, but no positive proof of this was to be seen, as soil covers the junction of the two rocks. In the syenite a small dyke, ten inches wide, of a fine grained gabbro (?) occurs; this was exposed for only three feet in length. The contact with the syenite was a sharp line as is shown by No. 535. The dyke rock is represented by No. 536. The gabbro proper retained its coarse grained character as near to the syenite as it was exposed. No. 537 is the gabbro in the exposure nearest the syenite.

### *Disappointment lake.*

This is also called Cheadle's lake. It is an irregular lake lying in secs. 3 and 4 of T. 63–8 and secs. 27, 28, 32, 33 and 34 of T. 64–8. Mica-schist occurs on the portage from Round lake. At the east end of the portage in the N. W. ¼ of S. W. ¼ sec. 3 is a low outcrop of schists, almost argillaceous in places. The strike here is N. 15° E., and the dip is vertical. The western shore of the lake has many large exposures of conglomeritic mica-schist cut in many places by fine red syenite. This syenite occurs in some amount on the portage to Snowbank lake (S. ½ of S. W. ¼ sec. 32) and is here seen cutting a peculiar gray rock. This gray rock (No. 539) seems to be a holocrystalline aggregate of gray feldspar grains among which are scattered hornblende prisms. In one place this gray feldspathic rock held many pieces of a darker rock, apparently a diorite; this is well shown by the specimen collected (No. 539). These pieces of diorite are of irregular shapes and all sizes up to those ten inches in diameter; none of them are lenticular in shape and they do not present the rounded outlines of pebbles. This gray rock lies

to the north of the portage and is between two ridges of mica-schist, but was not seen in contact with the schist. No. 539 is the fine red syenite which cuts the gray rock.

### *North of Disappointment lake*

Two small lakes, one lying in the N. ½ of sec. 27 and the other in the S. E. ¼ of sec. 21, T. 64–8, were passed through. The rock on the shores of both of these small lakes was massive in appearance and varied from a very siliceous graywacke to a hard, fine grained green rock, resembling the ordinary greenstone of the region. Most of the shore line of the former of these lakes was examined, but no rock was seen excepting that just spoken of.

## C. KEKEQUABIC LAKE AREA.

### *South of Kekequabic lake, in secs. 11 and 14, T. 64–7.*

On the portage, in the N. E. ¼ of N. W. ¼ sec. 11, is a ridge of soft dark greenish rock, which is composed largely of biotite (No. 540). An irregular lake, lying in the centre of sec. 11, has been called River lake. Its shores are made of a fine grained gabbro-like rock. This varies from No. 541, a rather coarse facies from the west end of the lake, to No. 542, of finer grain from the portage in the N. E. ¼ of S. E. ¼ sec. 11. Most of the rock, however, is finer grained than No. 541. In places this rock has small veins or streaks running through it; these are composed mostly of biotite. At times they are quite close together, as shown by No. 543, and again very few of them are seen. No general direction for these black streaks could be seen. On the north side of the central western arm of this lake the gabbro-like rock held many angular and twisted fragments of a reddish syenite similar to that found on Kekequabic lake, and also of a fine grained greenstone (No. 544). These fragments are of all sizes up to those a foot in diameter; they are very irregular in outline, none of them are rounded, and they are often much twisted and stretched. No. 545 shows some of the fragments in the enclosing rock.

A few rods back from the shore, on the south side of River lake and near the entrance to the southern of the western arms of the lake, is a westerly facing bluff made up mostly of the fine gabbro-like rock. In the face of the bluff is a small area of syenite (No. 546). This is rather fine grained and is composed of pinkish feldspar, hornblende and some biotite. The syenite was seen within six feet of the other rock, but at this place neither of them showed any change from their normal condition.

On the east shore of the lake, near the centre, is a very micaceous facies of the gabbro-like rock (No. 547). Just south of this is a gray condition, probably of the same rock (No. 548); this weathers reddish.

The shores of Shoofly lake, which lies mostly in the S. E. ¼ of sec. 11 and the N. E. ¼ of sec. 14, are made of the ordinary gabbro of the region; this is rather finer, especially near the northern end of the lake, than the main mass of the gabbro. In one place, on the north side of the western arm of the lake, is a rock similar to that which makes most of the shores of River lake. South of Shoofly lake, and about in the centre of the N. ½ of sec. 14, is a large hill of white or grayish weathering gabbro.

### *Kekequabic lake.*

On the south side of the little bay which extends into the N. E. ¼ of N. W. ¼ sec. 11, T. 64–7, is an outcrop of what has been called, in the former reports of this survey, chloritic syenite and chloritic gneiss. This rock has a considerable development on the shores of Kekequabic lake. Under the microscope it is seen to be a *pyroxene granite.* It is of a rather medium or fine grain and reddish color, and will be frequently referred to below. South of this outcrop and about 200 yards from the lake is an east and west running ridge made of a dark green biotite rock, similar to No. 540, which was taken from this ridge a short distance to the east. The pyroxene granite is again seen in low outcrop on the south side of the point, in the S. E. ¼ of S. W. ¼ sec. 2, T. 64–7. These two are the only exposures on the west side of the bay mentioned above. On the west side of this little point is a large outcrop of the pyroxene granite; it varies considerably within a few inches as to the amount of the pyroxene constituent. No. 549 shows the lightest colored and coarsest grained facies from this place. The rock presents an irregular layered appearance. These layers vary from an inch to ten inches in thickness, and even the same layer varies in thickness within a short distance. No difference in composition between the different layers could be made out, nor is there any arrangement, macroscopically visible, of the constituent minerals in such a manner as to cause splitting along certain lines. The rock did not show a tendency to split up into fine layers parallel to the larger ones. The rock has not yet been carefully studied in regard to the origin and significance of this structure. Fig. 5 represents the face of a small exposure of this granite and shows the regularity of the layers. The layers at this place dip from 10° to 15° towards the south.

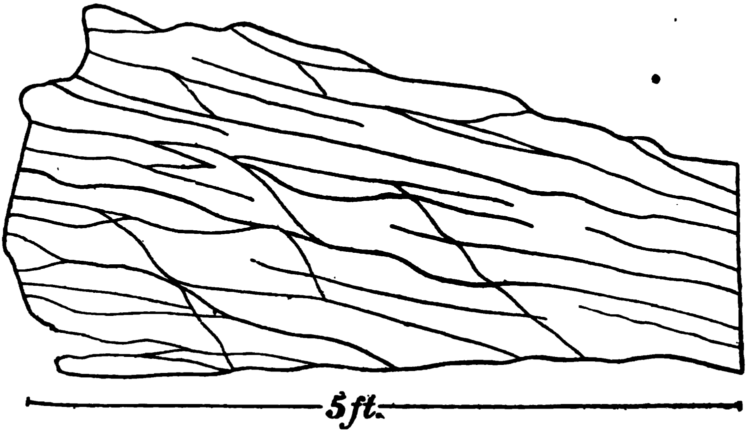

Fig 5. Sketch showing the parallel layers into which the pyroxene granite is broken in the S. E. ¼ S. W. ¼ sec. 2, T. 64-7, south shore of Kekequabic lake.

No other outcrops are seen along the south shore in sec. 2 and the S. E. ¼ of sec. 3, T. 64–7. On going south from the lake for a quarter of a mile, on the line between secs 2 and 3, no rock is seen *in situ*, although the ground rises very rapidly from the lake shore. In the S. E. ¼ of S. W. ¼ sec. 3, on the shore, is a dark colored fine grained chloritic rock (No. 550), which extends westward and seems to become the angular weathering chlorite-biotite rock described in the 15th (1886) Annual Report, page 364.

The little promontory (not shown on the plat), in the S. W. ¼ of S. W. ¼ sec. 3, T. 64–7, is made of the pyroxene granite, which here contains distinct porphyritic reddish feldspars. The rock is well represented by No. 551. There is in the granite a division into layers similar to that described above, but coarser and less noticeable, which here dips northward 15° to 20°. At the base of this promontory is a low outcrop of a dark aphanitic rock (No. 552) which resembles some of the hardened argillyte slates of Knife lake. Just west of the promontory the chlorite-biotite rock is again seen, and this extends along the shore in sec. 4 and out to the end of the point in the S. W. ¼ of N. W. ¼ sec. 3, T. 64–7. On this point the pyroxene granite is seen in contact with this chlorite-biotite rock. A piece of the granite was seen, apparently surrounded by the other rock, but no positive evidence as to the relative age of the two could be seen, although the granite seems to be the older. The contact between the two rocks is a pretty well defined line. No. 553 shows the granite from this place; No. 554 the contact; and No. 555 the chlorite-biotite rock, which here holds a small amount of red feldspar, not seen in it elsewhere. On the north side of this point the granite occurs in a large exposure. It is here finer grained than No. 553, and is represented by No. 556. It varies much, especially towards the west end of the exposure, and becomes darker colored and much finer grained, as is shown by No. 557. The chlorite-biotite rock is again seen at the extreme eastern edge of this point and in one place it is in contact with a small piece of the granite. On the north side of this point, near its base, is an uninterrupted exposure extending along the shore for thirty-five feet, and just east of it are other small exposures within a few feet of each other. Here there is a gradual change from a gray aphanitic rock much resembling some of the gray slate of this vicinity to the pyroxene granite, as represented by Nos. 556 and 557. The gray rock, however, shows no evidence of lamination or any definite slaty cleavage; it may be a very fine grained facies of the granite in which the porphyritic feldspars are lacking. As yet these specimens have not been studied microscopally. Nos. 601 to 615 represent this gradation; No. 601 is the gray rock; the specimens up to No. 612 were taken within distances of one to four feet going eastward from No. 601; Nos. 613, 614 and 615 occurred thirty to forty feet further east, and these pass into the facies of the granite represented by Nos. 556 and 557. From this point northward the rest of the west shore in sec. 4, T. 64–7, and the north shore in sec. 34, T. 65–7, were explored carefully for any trace of the pyroxene granite, but none was found.

The little island just northeast of the end of this point (S. W. ¼ N. W. ¼ sec. 3, T. 64–7,) has on its western end numerous angular fragments of dark aphanitic rock holding red feldspar crystals (No. 558). And on the south side of the island, and in some places on its west end, are also fragments of a dark conchoidally breaking argillyte (No. 559) very similar to No. 552 described above. These two rocks (Nos. 558 and 559) are undoubtedly in place just below the angular blocks. On the east end of the island is a small outcrop of a gray rock which has a fine grained granitic ground-mass holding very small porphyritic crystals of pyroxene and large ones of feldspar. This rock is numbered 560. It is the same rock as is found in considerable amount farther east on the shores and islands of this lake. This rock is found to be a very fine grained *pyroxene granite porphyry*, and will be spoken of in this report as such, or simply as *granite porphyry*. This rock was seen in sharp contact, in a loose block, with the black argillyte. Rocks Nos. 558 and 560 are probably different facies of the same rock; apparently intermediate stages were seen.

The island nearest the end of this point has a good sized bluff of granite near its centre; this is well represented by the specimens described above, Nos. 556 and 557; it occupies the north half of the island. On the south shore is a dark rock with a green chloritic ground-mass in which are blotches of hornblende (No. 561); this seems to pass into a fine grained condition (No. 562) which is seen in sharp contact with the granite, but the relative ages of the two was not determined.

On the east shore of the little bay which lies at the southern side of the base of this point (S. W. ¼ N. W. ¼ sec. 3, T. 64–7,) is a slaty rock which, however, appears perfectly massive, except in weathered fragments where the slaty structure is brought out; no evidence of lamination was seen. At the northeast corner of this bay the slate is a black almost conchoidally breaking argillyte. Here on the weathered surfaces appears a fine lamination which strikes N. 20° E. and dips 75° toward the east. This rock is similar to No. 559, and it is peculiarly spotted by small gray to whitish blotches. Those spots are not very numerous, but are often quite distinct; they are of all sizes up to those five mm. in diameter. No. 563 shows this spotted slate. Going west along the north shore of this little bay the black slaty rock is seen in several low outcrops; it is cut by small veins which stand out above the surface of the rock on weathered surfaces. Near the west end of the bay, in the S. E. ¼ N. W. ¼ sec. 4, T. 64–7, is a soft green schist (No. 564), which strikes northeast and dips 70° toward the northwest. This rock shows no lamination, but has a very pronounced schistose structure. Just west of this, near the northwest corner of the bay, is the green chlorite-biotite rock.

The large island in the E. ½ of sec. 3, T. 64–7, and the three smaller islands that lie just west and northwest of it are composed of the pyroxene granite. The rock varies somewhat in grain and in the amount of the pyroxene constituent present. No. 565, from the east end of the smallest of the three smaller islands, shows about the normal condition of this granite. No. 566 is a coarser grained facies from the southern end of the largest and most northerly of the three smaller islands. On the north shore of the large island, near its western end the granite varies from a fine grained condition, like No. 565, to a dark, fine grained facies (No. 567). At this place was also seen a small band or inclusion of a gray and black slaty rock (No. 568) in the granite.

On the east shore of the bay in the N. E. ¼ of N. W. ¼ sec. 11, T. 64–7, is a fine grained green chloritic rock (No. 569). This is roughly schistose in places and at the water's edge is seen to be conglomeritic. The pebbles are rounded and do not appear distinct on fresh surfaces, but where the rock is waterworn they are quite prominent. From this exposure a ridge runs eastward and a short distance from the shore the rock is distinctly laminated, as shown by No. 570. This exposure may have been a little displaced, but to all appearances it has not been. The dip is about vertical and the strike is N. 80° W. Just north of this and also in the S. W. ¼ of S. E. ¼ sec. 2, T. 64–7, are hills of fine grained pyroxene granite (No. 571). In the granite are a few dark inclusions of irregular outline; No. 572 is from one of these. The same fine grained pyroxene granite is seen in several places along the shore of the bay which lies in the E. ½ of S. W. ¼ sec. 2, T. 64–7, and the high hills just east of this bay are apparently composed of the same rock. These hills were visited in the E. ½ of S. W. ¼ of S. E. ¼ and N. E. ¼ of N. W. ¼ of S. E. ¼ sec. 2, and were found to be made of the same granite, well represented by No. 571. Syenite is also seen on the west side of the northward extension of this bay and on the point in the N. E. ¼ of S W. ¼ sec. 2. No other outcrops are seen northward along the shore in sec. 2, but on the point in the S. W. ¼ of S. E. ¼ sec. 35, T. 65–7 is a low exposure of a very fine grained facies of the granite (No. 576).

There is an island in the N. W. ¼ of N. W. ¼ sec. 2, T. 64–7, which is made up mostly of the pyroxene granite (No. 573); this varies somewhat in grain, but none was seen as fine as No. 571; it is noticeably porphyritic with reddish feldspars. On the west side of the island near the north end is a rock with a green aphanitic ground-mass in which are numerous glistening biotite scales,—No. 574. This rock is seen in contact with the granite; the contact line is sharp and distinct. The green rock is cut by many vein-like forms of a purple rock which is seen to be part of the granite, but they were not, actually, traced into the granite. No. 575 shows this rock in contact with the green rock. On a microscopic examination No. 575 is seen to be part of the granite. The two rocks were not apparently changed near the contact. Many angular and rounded fragments of the green rock are seen in the granite and a few fragments, or what appear to be such, of the latter, are seen in the green rock. The evidence of this exposure points to the more recent age of the granite.

About the foot of the shallow bay in the S. E. ¼ of S. E. ¼ sec. 35, T. 65–7, is an outcrop of a very light colored facies of the pyroxene granite porphyry (No. 577). Down at the water's edge this rock held a piece of a dark chloritic rock, similar to No. 574; this is probably an inclusion in the porphyry, but not enough was exposed to show this positively. A short distance east of this place a purplish condition of the granite porphyry is seen (No. 578). In fragments from the side of this exposure there is a distinct arrangement of the porphyritic feldspar crystals in approximately parallel position. This could not be seen very well in the rock *in situ*, but at one favorable place this arrangement was in planes, or apparently so, running about east and west and dipping N. about 45°. That this direction is constant in this place is not clearly shown. The rock contains few pyroxene prisms, but a few were seen one-eighth to one-quarter of an inch in length. A short distance further east, in the S. W. ¼ of S. W. ¼ sec. 36, T. 65–7, is an outcrop of fine grained pyroxene granite, similar to No. 571.

On the main shore, just south of the west end of Stacy island (the island just off the shore and near the center of the N. ½ of S. W. ¼ sec. 36), a few feet from the water, is a low knoll of the granite porphyry well represented by No. 578, although here the porphyritic crystals are not quite as abundant as in that number. A few rods back from this knoll a high, precipitous hill rises, probably 200 feet above the lake; this hill extends along the lake shore in the S. ½ of sec. 36, T. 65–7. Mr. Wood went to the top of the hill, but found it to be all made of the same rock as is seen at its base,—a fine grained facies of the pyroxene granite (No. 579). This granite and the granite porphyry were traced within 150 feet of each other, but no nearer. Nothing was seen to indicate a gradation between the two rocks.

The granite porphyry occurs on the south shore of the lake in several places in the S. ½ of N. E. ¼ sec. 36, T. 65–7 and S. W. ¼ N. W. ¼ sec. 31, T. 65–6. Careful search was made for any general direction for the long axes of the feldspar crystals in this porphyry, but none could be found. In the S. W. ¼ of N. E. ¼ sec. 36, T. 65–7, just back from the shore, is a cliff about eighty feet high. The lower half of this is composed of the granite porphyry, and the upper half of a green conglomerate similar to that described half a mile southwest from this place on Stacy island.* The exact line of contact between the two rocks was seen in only one place, but the two were traced within two to five feet of each other for some distance along the face of the cliff. The contact line remains nearly horizontal for some distance and then suddenly runs upward. There seemed to be no blending of the two rocks at their junction, but the porphyry was roughly schistose and softer than usual, while the conglomerate seemed harder and more crystalline. No. 580 represents the porphyry and No. 581 the conglomerate at the contact; these two specimens were taken within two inches of each other. No. 582 shows the porphyry about four feet from the conglomerate. The dip of the conglomerate seemed to be toward the south, but nothing definite could be determined about this. The southwest side of Stacy island has quite an extensive exposure of the granite porphyry, but the junction of this and the conglomerate and the diabase on the island was not found. The porphyry here is rather coarser grained than usual and carries considerable biotite,—No. 583. The island just west of this shows many outcrops of the porphyry along its shores, in fact, this was the only rock seen on the island.

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* 15th (1886) Annual Report, pp. 150-151.

On the northwest end of the little point in the S. W. ¼ of N. W. ¼ sec. 31, T. 65–6 (south side of the lake) there is a dark, medium grained diabase. And on the northeast corner of this point is a low outcrop of a fine grained, gray, apparently holocrystalline rock; the ground-mass is grayish and in it are small, black needles, probably of hornblende, and a few scattered, rather irregularly outlined, feldspar individuals. There are also a few rounded pebbles, up to those two inches in diameter, scattered through the rock. The specimens collected (No. 593) show some of the pebble forms. Some of these pebbles are seen to be sub-angular, but most of them are rounded. They seem to be scattered irregularly through the rock and lie in no definite planes or layers; there is nothing in the rock to show any sedimentary lamination or bedding; it appears perfectly massive. This rock is seen in several outcrops in the N. E. ¼ of S. W. ¼ sec. 31, T. 65–6, and the shore is here usually lined with fragments of it. In the eastern part of this one-sixteenth section is quite an extensive exposure a short distance back from the shore. Here the pebbles, which have been steadily increasing in abundance eastward from the first mentioned outcrop, are very numerous. It would be almost impossibe to find any surface a foot square in the rock at this place which would not contain one or more pebbles, and many areas of this size would include as many as twenty. The rock is here represented by No. 594 and pebbles from it by 594A. This rock extends along the shore in a few outcrops nearly to the east line of sec. 31. The pebbles grow less abundant on going east from No. 594. No. 595 shows a more highly crystalline condition of this rock from the S. E. ¼ N. E. ¼ sec. 31. The noticeable features of this rock are its sharply outlined, rounded and sub-angular pebbles and the few scattering, white, apparently porphyritic, feldspar crystals, sometimes a quarter of an inch in length. No bedding, lamination or definite arrangement of the pebbles could be seen in the rock. It seems that this rock is a metorophosed conglomerate, and it strongly reminds one of certain facies of the Ogishke conglomerate. In one place in the last mentioned one-sixteenth section there is a rough, parallel jointage in the rock; these joints dip southward about 25°.

In the eastern side of the above $\frac{1}{16}$ section is a low bluff of fine grained diabase and granite porphyry. The two rocks are seen in contact; the line between them is sharp and about vertical, but quite irregular, angles of each projecting into the other. There was nothing seen to determine the relative ages of the two rocks. No. 596 shows the granite porphyry about three feet from the contact; No. 597 is the same at the contact. No. 598 is the diabase at the contact, and No. 599 is the same six feet from the contact. No. 600 shows a coarser grained condition of the same also six feet from the contact. These last three grade into each other. It may possibly be that the specimens Nos. 598 and 599 are altered black slate, but this cannot be told macroscopically, and to all appearances they are continuous with and not to be separated from No. 600, which is a distinct diabase. The south shore of the lake, from this place to its extreme eastern end, was examined carefully for other outcrops of the granite porphyry, but none were found.

On the north shore of the lake, in the W. ½ of N. E. ¼ of N. W. ¼ sec. 31, T. 65-6, there is an exposure of the granite porphyry which has above it, and on both sides of it at the water's edge, a green rock seemingly the same as the green schists found a short distance to the west. Here the green rock appears perfectly massive, except in a few places, where there is a very indistinct lamination, which is not sufficiently developed to enable one to determine the strike and dip. No. 616 is the porphyry thirty feet from the green rock; the porphyry holds a few small rounded areas of greenish material with rather indistinct outlines; one of these is shown in the specimen of the porphyry collected here (No. 616). The two rocks were traced within two feet of each other, but the exact contact was not seen. Nearest to the green rock the porphyry seemed to be finer grained (No. 617). No. 618 shows the green rock within thirty inches of No. 617, and the ill-defined reddish blotches which are seen in the green rock near the porphyry. No. 619 is the green rock about fifty feet from the porphyry. On the east side of this exposure the two rocks are seen close together. Here the porphyry held pieces of greenish material (No. 620) up to ten inches across; there was no very sharp line between these and the porphyry, but owing to the moss and lichen covered condition of the rock these green areas could not be well outlined. Search was here made for some general direction for the long axes of the feldspar crystals of the porphyry, but none could be found.

With the exception of a small area of fissile green schist on its western side, the point on which are the corners of secs. 29, 30, 31 and 32, T. 65–6, is made entirely of the granite porphyry. It here reaches its most typical development. This is the first exposure of the porphyry on the north side of the lake east of that described just above. Green slate is seen just north of this point, but between this and the porphyry there are no exposures; however, at the nearest point to these green slates the porphyry is finer grained than usual, as is shown by No. 621. A number of the largest pyroxene crystals were collected from the rock on this point, and also some of the feldspars, which showed dark centres. Very few inclusions were found here; probably not more than thirty were seen; these varied from half an inch to ten inches in diameter. They are mostly greenish in color and are not very sharply outlined, as is shown by No. 621A. No. 621B is from an irregularly but sharply outlined piece ten inches across. No. 621C is from an oblong piece, ten by five inches in area; around this piece there is distinct evidence of flowage, as is shown by the arrangement of the porphyritic feldspars.

Just south of the corner of the bay in the S. E. ¼ of S. W. ¼ sec. 36, T. 65–7, is a large ridge of pyroxene granite, spoken of before. (See No. 579 and accompanying description.) The eastern end of this ridge is made of a fine grained, flesh-colored rock (No. 622), a condition of the slates of the region, but no structural planes can be seen in it. This is in contact with the granite; the line between the two could not be clearly seen, but it seemed to run about vertical. No. 623 is the granite about thirty feet from the contact. No. 624 is the same at the contact, and No. 625 shows the slate at the contact. The last two specimens were taken within an inch of each other. This slate continues eastward and northeastward for about two hundred yards; it varies somewhat, as shown by Nos. 626 and 627. The relation between this rock and the dark, hard slates on the shore just north of this could not be determined.

In the N. E. ¼ of N. E. ¼ sec. 36, T. 65–7, where the granite porphyry overlies the greenstone,* two specimens of the former were collected. No. 628 is fine grained and was taken just at the contact of the two rocks; No. 629 is coarser grained, taken fifty feet from the contact. Careful search was made for some general direction of the long axes of the porphyritic feldspars, but their directions varied much; however, there were more places in which they ran about east and west than where they ran in other directions.

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*This place has been described and figured in the 15th (1886) Annual Report, pp. 154, 367.

### *South from Kekequabic lake in sec. 31, T. 65–6, and secs. 6 and 7, T. 64–6.*

A trip was made south from the lake through the S. E. ¼ of sec. 31, and through the E. ½ of sec. 6 to the little pond on the south line of this section east of the quarter post. From this pond I went through sec. 7 to the lake which lies in the S. ½ of this section and the N. ½ of sec. 18. The description will begin at Kekequabic lake and go southward over the high hill in the N. E. ¼ of sec. 6 to the lake just mentioned.

At the shore, in the S. W. ¼ N. E. ¼ sec. 31, the conglomerate, already described under Nos. 593, 594 and 595, is seen; this continues southward for at least an eighth of a mile. The pebbles become less numerous, but no less sharply outlined, on going away from the lake, and the rock becomes more coarsely crystalline and holds more of the apparently porphyritic white feldspars,—No. 630. No evidence of bedding was seen in this conglomerate. Beyond this and within fifty yards of the last exposure of conglomerate there are outcrops of slate. This slate varies from a dark almost black argillyte to one that is quite light gray. The lamination of the slate was twisted in some places, but as a rule this coincided with the slaty cleavage. The dip and strike were taken in many places before reaching the top of the large hill, whose summit lies in the N. E. ¼ of sec. 6; the dip was vertical and the strike varied from N. 35° E. to N. 55° E. The slate was intimately interbedded with a dark gray to greenish grit, but the lines between the two rocks were quite distinct. The bands of each varied from those a fourth of an inch across to those that were fifty feet or more in width. The grit held angular fragments of the slate and bands of the slate that were abruptly cut off; there were also places where bands of the slate were faulted and the grit existed between the faulted and broken ends of the slate bands. This grit makes up about half of the exposures to the hill top, but no exposure was composed entirely of this or of the slate alone. No. 631 is the black slate; No. 632 the grit, and No. 633 shows, as well as a hand specimen can, the intimate interbanding of the two. At the top of the high hill the grit is coarser grained than usual, as is shown by No. 634. The strike continues to be northeasterly until coming into the S. E. ¼ sec. 6, where it changes to N. 20° E., and a short distance farther south to direct north and south; the dip still remains vertical. This north and south strike continues to the pond which lies on the south line of section 6 east of the quarter post. No. 635 shows another condition of the grit resembling graywacke from just north of this pond. In this there is seen indistinct lamination, but the other specimens of the rock do not show it; the rock (grit) elsewhere appears perfectly massive except for its interbanding with the slates. South of this pond the strike again swings round to northeast and the dip remains vertical.

About a quarter of a mile south of this pond is an outcrop of a porphyritic rock which is probably the same as the granite porphyry of Kekequabic lake. About seventy-five feet of this rock was exposed, the slates occurring both north and south of it within less than a hundred feet. The porphyry is numbered 636. The weathered surfaces of it show a rough schistose structure which runs N. 35° E. and stands vertical; however, this structure is not seen on freshly broken surfaces. The feldspar crystals are often arranged with their long axes parallel to the direction of the schistosity. The northeast strike of the slate and grit continues as far as they were seen,—*i. e.* almost to the lake which lies in the S. ½ of sec. 7 and the N. ½ of sec 18. We struck this lake about the centre of its north shore in the S. E. ¼ S. W. ¼ sec. 7. A short distance before reaching this lake the slate disappears and the grit, similar to Nos. 632 and 635, both of which facies here often show fine lamination on weathered surfaces, becomes in places conglomeritic and harder (No. 637). The pebbles are mostly rounded, some few are subangular, and they are chiefly of slate and a reddish granite porphyry, a pebble of which is shown in the specimen collected. This conglomerate shows no signs of lamination or schistosity. A short distance further south and almost at the lake shore is a more crystalline conglomerate holding pebbles of the same or similar reddish granite porphyry, and also of a fine grained red granite or syenite which resembles the pyroxene granite already mentioned so often. This conglomerate is shown by No. 638. In this rock, and also in No. 637, the pebbles varied from quite small ones up to those eight inches in diameter, but most of them were one to three inches across. In some places the pebbles were quite numerous and in others there were but a few to be seen. No definite arrangement of the pebbles in planes nor any elongation of them in one direction was seen.

The eastern half of the north shore of this lake (lying in the S. ½ of sec. 7 and N. ½ sec. 18) has some outcrops of the conglomerate represented by No. 638. On the east shore of this lake there are no outcrops until coming nearly to the south line of sec. 7. A short distance north of this line the ordinary gabbro of the region is seen. It is somewhat finer grained here than is usual, as is shown by No. 639. On going south along the shore a little farther the gabbro becomes coarser, similar to the usual coarse grained gabbro of the Mesabi range.

The object of this trip south from Kekequabic lake was to find how far south the conglomerate, described under Nos. 593, 594 and 596, extended, and to look for an eastern extension of the pyroxene granite which is seen in the E. ½ of sec. 2, T. 64–7. However, no granite nor any trace of it was seen. Numerous exposures of rock were seen, and there was probably no distance of a hundred yards where outcrops were wanting, until just before coming to the small lake mentioned above. And here there were not enough exposures to satisfactorily trace the conglomerate represented by No. 637 into that represented by No. 638. Still everything, except the more crystalline condition of No. 638, seems to point to their identity. The high hill passed over just south of Kekequabic lake seems to be at least 350 feet above the lake. This was thought to be the case on comparing it with Mallman's peak, which is 250 feet above the lake.*

*Small lake in the S. E. ¼ of sec. 36, T. 65–7.*

On the hill just north of the east end of this lake is a fine grained diabasic rock (No. 584). In places this is massive and again slaty. The strike of the slaty structure is N. 80° W., and the dip is towards the north 65° to 70°. Toward the base of this hill is a gray porphyritic rock with indistinct white feldspars in it (No. 585). This was seen in contact with the diabase rock and is found both above and below it, but the exact contact was seen in but one place where the two rocks were separated by a sharp line. Farther up on the hill the porphyry is represented by No. 586, which much resembles the pyroxene granite found a mile to the west. There were some apparently intermediate stages between Nos. 586 and 585, but no continuous exposures connected them. No. 587 represents another facies seen in contact with the slaty diabase (No. 584); this was apparently a stringer of the porphyry in the diabase. The same porphyry is again seen in a hill north of the centre of the lake and is in sharp contact with the slaty diabase. The latter is confined mostly to the upper part of the hill while the porphyry occurs near the water. No. 588 represents this porphyry from the north side of the lake.

At the northwest corner of the lake black argillytes are seen. They show no distinct bedding. On the west side of the lake near the north end is an exposure of the fine grained pyroxene granite (No. 589). And a short distance farther south is a hill whose base is made of the same granite, but of somewhat coarser grain (No. 590).

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*The lake described above as having gabbro on its south shore is in the N. ½ of N. E. ¼, T. 64-7, and not in secs. 7 and 8, T. 64-6.

There is only one outcrop on the south side of the lake; this is a fine grained granite porphyry (No. 591) similar to that described from Kekequabic lake as pyroxene granite porphyry. I looked carefully for a definite arrangement of the feldspar crystals here, but none could be seen. Those, however, as seen in many places on Kekequabic lake, seemed to show evidence of a flowage in the rock before solidifying. On the east shore of the lake is a porphyry similar to No. 588. Here are a few irregularly shaped inclusions in the porphyry; No. 592 is from one of these. No rock intermediate between Nos. 588 and 591 was seen.

### *East of Kekequabic lake in secs. 28 and 29, T. 65-6.*

A portage runs eastward from the most easterly point of Kekequabic lake to a small lake in the W. ½ of S. W. ¼ sec. 28. On this portage the hard black and gray argillytes, found just to the west, are also seen. The strike and dip were taken in one place; the former was N. 20° E. and the latter about vertical. On the east end of the portage is an aphanitic dark gray rock holding white feldspar crystals (No. 640); it also holds a few rounded pebble-like forms of rock similar to itself. On this portage and a short distance from the shore of the small lake this rock becomes softer and schistose and is not so distinctly porphyritic,—No. 641. It holds many rounded and subangular pebbles of fine grained granite, gray argillyte and a rock similar to No. 640. These pebbles present all the appearances of being water-worn and rounded; they are in places arranged in rough planes that run N. 25° E. and stand vertical. On the east side of the lake is an exposure of rock similar to No. 540, and on the same side nearer the north end is a large exposure of a peculiar gray granitic rock holding many small feldspars (No. 642). This is probably a metamorphosed grit. Back from the shore a little ways this rock becomes finer grained and darker in color, and is seen in sharp contact with a fine grained diabase (No. 643), which is probably in the form of a dyke. No. 644 shows this granitic rock at the contact, but this may be part of the rock similar to No. 641. North of this and extending to the portage is rock similar to No. 641; it is decidedly conglomeritic. I noticed a few scattered greenish inclusions or pebbles in No. 542.

From this lake is a portage running north for about fifty yards to another small lake. According to the plat this ought to be Zeta lake, but very probably the bay that is represented at the southwest corner of Zeta lake is separate from that lake. On the portage from this small lake to Zeta lake the argillaceous slates again occur; they here strike N. 20° E. and dip 80° to 85° towards S. 20° E.

## D. SAGANAGA LAKE AREA.

The work on this area was confined mostly to its southwestern and western borders. The limits of the granite were traced pretty accurately from the east side of sec. 15, T. 65–5, west and northwest to the E. ½ of sec. 24, T. 66–6, where the western line of the granite crosses the international boundary.

### *West Sea Gull lake.*

The southwest corner of the point that is crossed by the south line of sec. 8, T. 65–5, is composed of a coarse grained gray granite (No. 645). Just east of this the rock is much decayed and very schistose, as shown by No. 646. This is undoubtedly only a decayed portion of the granite, and the two are not separated by any line. East of this the granite, like No. 645, is again seen, and it also outcrops on the north side of a little island just south of this point. There are no outcrops at the end of the little bay in the N. W. ¼ of N. E. ¼ sec. 17, but a short distance to the east are rounded knolls of granite. Here the rock is darker colored and carries less quartz than most of the granite on the lake; this facies is shown by No. 647. On the south shore of this bay and near its eastern end is a low outcrop of the ordinary granite, and a short distance to the west are large, bare, rounded domes of a dark green slaty rock which appears massive in places. At the water's edge the granite was seen in contact with the slaty rock, and it also held angular fragments of the same. The granite at the contact was coarse grained and similar to No. 645. The green slaty rock is represented by No. 648. The rounded domes of the green slate are cut by numerous branching veins or dykes of granite, which is coarse grained and similar to No. 645; it is shown by No. 649. These veins are of all sizes up to those twenty feet in width; the sides of them are not finer grained than the centres. A second set of granite veins, few in number, also cut the green rock and the coarse granite veins; this second series is composed of a fine grained reddish granite (No. 650), and these veins are of finer grain near their edges than at the centre. This same rock was seen cutting the ordinary granite on the north side of the bay. On the west shore of the bay in the N. E. ¼ of N. W. ¼ sec. 17, is a massive aphanitic greenstone (No. 651). On going north along this shore this rock seems to pass into a massive diabasic rock, which comes in contact with the granite, which holds pieces of the diabase and sends stringers into it. No. 652 is the diabase from the granite contact. Granite occurs in a few outcrops along the shore in the

A small stream flows from this lake east to Sea Gull lake, in the S. E. ¼ N. W. ¼ sec. 16, and just south of the stream is a short portage between the two lakes. Granite occurs a few feet south of this portage.

### *Sea Gull lake.*

The western shore of this lake, in sec. 16, T. 65–5, was rather carefully examined. There were many exposures, but these were all granite except on the south side of the bay in the N. E. ¼ S. E. ¼ sec. 16, and on the shore in the S. E. ¼ S. E. ¼ sec. 16. Here were outcrops of the same hardened mica-schist, varying to a green slaty rock, as described above. (Compare Nos. 669 and 670.)

Where the east line of sec. 16 cuts the south shore the granite is seen; here it is chloritic, rather decayed and somewhat schistose, —No. 671. Back from the shore a few rods and just west of the section line is a ridge of fine grained mica-schist, varying to chloritic schist. Farther south and on the north side of the east and west ridge, on which is the southeastern corner of sec. 16, is a small amount of fine grained granite (No. 672), probably a stringer from the main granite mass. The south side of this ridge is made up of a greenish mica-schist (No. 673); here the strike of the schistose structure is N. 70° W. and the dip is vertical. A short distance further south is another ridge of the same rock. No lamination was seen in this schist; it varies from a fine mica-schist, like No. 673, to rock similar to Nos. 651 and 670. On this last ridge is a small amount of a gray quartz porphyry in the schists; this appeared like a band running parallel with the schists;—No. 674.

### *Red Rock lake.*

The outcrops on the west end of the bay that projects into the N. E. ¼ N. E. ¼ sec. 5, T. 65–5, are all granite. The bay which lies in the E. ½ N. E. ¼ sec. 32 and W. ½ N. W. ¼ sec. 33, T. 66-5, was examined. Here there are several outcrops of the ordinary granite.

On going north from West Sea Gull lake the granite becomes coarser in grain and more pink in color; it is hornblendic rather than chloritic. The quartz grains are especially large,—commonly a quarter of an inch across and sometimes as much as half an inch. Frequently one-third of the rock is made up of these large quartz grains.

### *Saganaga lake.*

The coarse grained granite of Red Rock lake is found also on Saganaga lake. No. 686 from the point in the S. W. ¼ N. E. ¼ sec. [illegible], T. 66–5, fairly represents the granite of the main part of Sag-

anaga lake. It is of decidedly coarse grain and of a pinkish color. The large irregular areas of quartz are very noticeable. The feldspar is pinkish and sometimes yellowish. Hornblende is present in considerable amount and is more or less changed to chlorite.

On the east end of a long island which lies just south of the point in the S. W. ¼ N. E. ¼ sec. 22, T. 66–5, is a a diabase dyke in the granite. This dyke is ten feet in width and has a north and south direction.

The island which lies mostly in the S. E. ¼ N. W. ¼ sec. 14, T. 66–5, is composed of a rock which varies from a fine grained syenite, made up almost completely of feldspar and very little hornblende, to a very coarse grained syenite of the same kind, and again to a rock composed mostly of feldspar and quartz, the latter in very large grains. In places it is porphyritic and has a reddish feldspathic ground-mass, in which are red feldspar crystals and sometimes quartz crystals. Disseminated through the rock in veins, and also in small grains, is a dark violet fluor spar. There are also some few small yellow grains in the rock which resemble talc. At the north side of this island is a large mass of white quartz which extends along the shore for over a hundred feet. This quartz mass was not seen in other places on the island. Mixed in with the quartz are fluor spar, yellow talc and red feldspar; the latter often shows cleavage faces eight or ten inches across. Small quartz crystals are seen in cavities; these crystals vary from colorless ones to those that are purple and even black. The rock from this island is represented by Nos. 676, 677 and 678.

In the N. E. ¼ N. W. ¼ sec. 14, T. 66–5, south side of the large island crossed by the north line of this section, the rock appears to be porphyritic with large quartzes; this is probably a decayed condition of the ordinary granite, the quartz being the only mineral unaltered. This rock is represented by Nos. 679 and 680. This rock is seen further east in the same 1/16 section along the shore of the island. In the S. W. ¼ S. E. ¼ sec. 11, the ordinary granite occurs, and this is also seen in several places in the S. ½ of sec. 11, on the west shore of this large island.

All the outcrops seen along the shore in secs. 10 and 9, T. 66-5, were of the usual coarse grained granite. On the little island in the extreme southeast corner of sec. 8 the granite is seen in contact with a fine grained reddish aplite, which seems to be in the form of a dyke. The granite did not appear to be changed at the contact, but the other rock was finer grained. No. 682 shows this aplite ten feet from the contact, and No. 681 is the same from the contact. The shore was followed pretty closely in secs. 17, 18 and

N. W. ¼ of the last mentioned $\frac{1}{16}$ section, but before coming to the north line of sec. 17 the aphanitic greenstone again appears. This is seen where this section line cuts the shore, and also in several places in the S. W. ¼ of S. W ¼ sec. 8, T. 65–5. It varies from a rock like No. 651 to one that is harder and gray to greenish in color and resembles a very compact and fine grained graywacke (No. 653). Granite is again seen on the blunt point which is touched by the west line of sec. 8 south of the quarter post.

On the shore in the N. W. ¼ N. W. ¼ S. W. ¼ sec. 8, T. 65–5, and also at the west side of the same $\frac{1}{64}$ section, where the west line of the section crosses the shore, are outcrops of conglomerate. The matrix of the conglomerate is gray to greenish in color, quite coarse and full of quartz grains. In this matrix are many pebbles, among which red jaspilyte is conspicuous. No. 654 shows this conglomerate. It is part of the Ogishke conglomerate which is seen in so extensive development to the southwest on Ogishke Muncie lake. There is nothing at this place to definitely show the dip and strike· This conglomerate rises in a ridge just west of the shore, and in places the matrix is entirely free from pebbles and quite schistose. This schistose structure runs N. 35° E. and stands vertical. A short distance further west, but separated from the conglomerate by low ground where there are no exposures, is a ridge of granite running northeast and southwest. This granite does not differ materially from that found at the lake shore; it is represented by No. 655. This granite ridge is about 100 feet wide; beyond it the conglomerate again appears and extends westward for at least a quarter of a mile from the lake. Beyond this is low ground with no exposures. On this last ridge the granite and conglomerate are seen in contact. The granite runs in bands in the conglomerate, thus giving the appearance of "interbedded" granite and conglomerate. These bands of granite vary from one to thirty feet in width, and about a dozen of them were seen. The contact lines between the granite and conglomerate are distinct, but rather irregular; however, they do not run across the strike of the conglomerate for more than six inches at a time. In some places it is rather difficult to tell which rock is under foot, but when the two rocks are seen together they are easily distinguished. The granite does not vary in grain, especially at the contact, but is of a uniformly coarse grain. No. 656 shows the conglomerate at the contact, and No. 657 is the granite from the same place. No. 657A is the granite four feet from the contact. No. 658 shows a more crystalline condition of the conglomerate matrix. Interbedded with the conglomerate is a small amount of argillaceous slate. The matrix varies from that shown by No. 654 to a fine grained green facies shown by No. 659. Bands of the matrix free from pebbles are common, and in such cases the rock is occasionally laminated. The strike at a place 100 yards east of the granite bands is N. 10° E., but near these bands it varies from N. 10° W. to exact N. and S.; the dip in all cases is vertical.

The granite is again seen on the northeastern side of the round point in the S. W. ¼ of S. W. ¼ of N. W. ¼ sec. 8, and also on the point just east of this. At the southwest corner of the bay, which runs into the S. E. ¼ of N. E. ¼ sec. 7, is a green rock similar to No. 651; it is cut by the granite and is also seen in sharp contact with a fine grained purplish porphyritic rock, which seems to be in the form of a dyke, although this could not be definitely seen. This porphyritic rock is the same as Nos. 660 and 661. On the northwest shore of this bay is a ridge of granite. Granite is also seen in several places on the north shore of the bay, and in one place is in contact with a purplish rock, which is much decayed and resembles a porphyrite. The line between this rock and the granite is very distinct, and the former seems to cut the latter in the form of a dyke. The granite is unchanged at the contact, but the other rock here seems to be finer grained than usual. No. 660 shows this porphyrite (?) from the contact, and No. 661 is the same twenty feet from the granite.

Along the west shore of the lake the granite is seen in several outcrops in the N. E. ¼ of N. W. ¼ sec. 8 and S. W. ¼ sec. 5. Near the end of the point in the N. E. ¼ S. W. ¼ sec. 8 is a diabase dyke in the granite. This dyke is also seen in the bay on the west of this point. No. 662 represents the diabase of this dyke; it is finer grained near the edge. The same dyke is also seen on the west and east sides of the end of the point in the N. ½ of S. E. ¼ sec. 5. It has an east and west direction and varies from thirty to forty feet in width. On going west from the southwest side of the bay in the N. W. ¼ S. W. ¼ sec. 5 the same dyke is again seen in contact with the granite, and both rocks form a ridge that runs west from the lake for an eighth of a mile. Beyond this (west) is a swamp with no exposures, and then not less than a quarter of a mile from the lake is a ridge running northeast and southwest. This ridge is made of a fine grained laminated slate (No. 665), which varies from a gray to a green argillyte. The lamination and slaty structure coincide and strike N. 15° E. and stand vertical. South of this ridge a few rods is another composed of a green to gray grit (No. 664), which is like the matrix of the conglomerate above described—Nos. 654 and 659. No pebbles are visible in this rock, nor is there any lamination, but in it are a few narrow bands of slate similar to No. 663. These stand vertical and strike N. 30° E.

The granite is seen in several outcrops on the shores of the bay in the centre of the N. ½ sec. 5, and also on the point on the east side of this bay. The east shore of the point in the S. E. ¼ S. E. ¼ sec. 8 was also examined and found to be composed of granite.

The granite of West Sea Gull lake varies considerably in grain and also in the amount of chlorite or hornblende present. The fresh rock is a hornblende granite, but in many places this has been completely changed to chlorite. There seem to be two feldspars present,—a yellow and a pink one. No. 675 is as fresh as any of the granite of this lake and may be taken as a typical example of it. This specimen was taken from the east side of an island in the S. W. ¼ S. E. ¼ sec. 8.

### *Small lake in the N. W. ¼ of N. W. ¼ of sec. 8, T. 65-5.*

This lake is not shown on the government plat. On the east and north shores of the lake no rock exposures were seen. On the west shore near the north end is a ridge composed of the Ogishke conglomerate similar in every respect to that described from West Sea Gull lake in this same section. The conglomerate was traced west over the ridge for a short distance; the pebbles became fewer in number and the rock in places was slaty, almost exactly like No. 663. At one place the slaty rock was crumpled as if it had been pressed in a direction parallel to the strike; this was seen for only a short distance. In places the matrix showed a lamination and again it was broken into long flags. The lamination, the long direction of the flags and the banding and slaty cleavage of the slaty areas were all parallel and stood vertical; the dip was N. 15° E.

On the west side of the lake near the south end the granite is seen at the shore. It is chloritic and holds large quartz grains and reddish feldspars,—No. 665. The conglomerate is seen not more than an eighth of a mile west of the shore, but the junction of it and the granite was not found. What is said about the conglomerate in the last paragraph will apply equally well here, except that the strike is N. 20° E. Back from the shore the granite becomes schistose in places; this schistose structure stands vertical and strikes N. 20° E. Here the rock is similar to No. 665, excepting for this schistosity. A little further west the granite has changed to a yellow rock holding large quartz grains,—No. 666.

This and the conglomerate were separated by several yards of soil where there was but one exposure. This exposure is within twenty feet of the conglomerate; the rock is shown by No. 667, which appears to be a more decayed part of the granite. On the west side of this exposure there seems to be, although this could not be distinctly made out, an interbanding of rock similar to No. 667 and a rock similar to this, but finer grained and greener. It is, however, possible that this last is but a less weathered condition of the former, and that they are both decayed conditions of the granite. The two rocks (if there are two) are shown by No. 668. Twenty feet west of this is the conglomerate with the matrix like No. 664.

No other rock exposures occur on this lake, but between its southeast corner and West Sea Gull lake is a knoll of the ordinary granite.

### *Small lake in the S. ½ of N. W. ¼ of sec. 16, T. 65-5.*

From the foot of the bay of West Sea Gull lake, in which are the corners of secs. 8, 9, 16 and 17, a portage leads south to this small lake. The ordinary granite is seen in two or three places on and near this portage trail. Granite also occurs where the west line of sec. 16 cuts the north shore of the little bay that projects into the S. E. ¼ N. E. ¼ sec. 17, and also a short distance on either side of this line. On the west side of this little bay is a rounded hill, the northern part of which is composed of granite and the southern part of a hardened mica-schist (No. 669), which in places looks almost like a fine diabase. The granite is in sharp contact with this rock and cuts it with many vein-like forms. These veins are like the granite elsewhere and differ only in being finer grained in places. The whole exposure much resembles that seen in the N. W. ¼ N. E. ¼ sec. 17, West Sea Gull lake, and described under Nos. 647 to 650.

Back from the shore at the southwest corner of this little bay the same hardened mica-schist is seen, and it occurs again within a few feet of where the west line of sec. 16 cuts the south shore of this bay. Continuing along the southwestern shore of the lake more of the hardened mica-schist is seen; it varies to a green slaty rock and also to a green siliceous schist (No. 670). These were all cut by granite veins. On the south shore near the east end of the lake the granite is seen in a large outcrop. No outcrops were seen on the north shore of this lake excepting on the little point in the centre of the N. ½ S. W. ¼ N. W. ¼ sec. 16, and on the small island just off this point; here the rock was granite.

A small stream flows from this lake east to Sea Gull lake, in the S. E. ¼ N. W. ¼ sec. 16, and just south of the stream is a short portage between the two lakes. Granite occurs a few feet south of this portage.

### *Sea Gull lake.*

The western shore of this lake, in sec. 16, T. 65–5, was rather carefully examined. There were many exposures, but these were all granite except on the south side of the bay in the N. E. ¼ S. E. ¼ sec. 16, and on the shore in the S. E. ¼ S. E. ¼ sec. 16. Here were outcrops of the same hardened mica-schist, varying to a green slaty rock, as described above. (Compare Nos. 669 and 670.)

Where the east line of sec. 16 cuts the south shore the granite is seen; here it is chloritic, rather decayed and somewhat schistose, —No. 671. Back from the shore a few rods and just west of the section line is a ridge of fine grained mica-schist, varying to chloritic schist. Farther south and on the north side of the east and west ridge, on which is the southeastern corner of sec. 16, is a small amount of fine grained granite (No. 672), probably a stringer from the main granite mass. The south side of this ridge is made up of a greenish mica-schist (No. 673); here the strike of the schistose structure is N. 70° W. and the dip is vertical. A short distance further south is another ridge of the same rock. No lamination was seen in this schist; it varies from a fine mica-schist, like No. 673, to rock similar to Nos. 651 and 670. On this last ridge is a small amount of a gray quartz porphyry in the schists; this appeared like a band running parallel with the schists;—No. 674.

### *Red Rock lake.*

The outcrops on the west end of the bay that projects into the N. E. ¼ N. E. ¼ sec. 5, T. 65–5, are all granite. The bay which lies in the E. ½ N. E. ¼ sec. 32 and W. ½ N. W. ¼ sec. 33, T. 66-5, was examined. Here there are several outcrops of the ordinary granite.

On going north from West Sea Gull lake the granite becomes coarser in grain and more pink in color; it is hornblendic rather than chloritic. The quartz grains are especially large,—commonly a quarter of an inch across and sometimes as much as half an inch. Frequently one-third of the rock is made up of these large quartz grains.

### *Saganaga lake.*

The coarse grained granite of Red Rock lake is found also on Saganaga lake. No. 686 from the point in the S. W. ¼ N. E. ¼ sec. [illegible], T. 66–5, fairly represents the granite of the main part of Sag-

anaga lake. It is of decidedly coarse grain and of a pinkish color. The large irregular areas of quartz are very noticeable. The feldspar is pinkish and sometimes yellowish. Hornblende is present in considerable amount and is more or less changed to chlorite.

On the east end of a long island which lies just south of the point in the S. W. ¼ N. E. ¼ sec. 22, T. 66-5, is a a diabase dyke in the granite. This dyke is ten feet in width and has a north and south direction.

The island which lies mostly in the S. E. ¼ N. W. ¼ sec. 14, T. 66-5, is composed of a rock which varies from a fine grained syenite, made up almost completely of feldspar and very little hornblende, to a very coarse grained syenite of the same kind, and again to a rock composed mostly of feldspar and quartz, the latter in very large grains. In places it is porphyritic and has a reddish feldspathic ground-mass, in which are red feldspar crystals and sometimes quartz crystals. Disseminated through the rock in veins, and also in small grains, is a dark violet fluor spar. There are also some few small yellow grains in the rock which resemble talc. At the north side of this island is a large mass of white quartz which extends along the shore for over a hundred feet. This quartz mass was not seen in other places on the island. Mixed in with the quartz are fluor spar, yellow talc and red feldspar; the latter often shows cleavage faces eight or ten inches across. Small quartz crystals are seen in cavities; these crystals vary from colorless ones to those that are purple and even black. The rock from this island is represented by Nos. 676, 677 and 678.

In the N. E. ¼ N. W. ¼ sec. 14, T. 66-5, south side of the large island crossed by the north line of this section, the rock appears to be porphyritic with large quartzes; this is probably a decayed condition of the ordinary granite, the quartz being the only mineral unaltered. This rock is represented by Nos. 679 and 680. This rock is seen further east in the same 1/16 section along the shore of the island. In the S. W. ¼ S. E. ¼ sec. 11, the ordinary granite occurs, and this is also seen in several places in the S. ½ of sec. 11, on the west shore of this large island.

All the outcrops seen along the shore in secs. 10 and 9, T. 66-5, were of the usual coarse grained granite. On the little island in the extreme southeast corner of sec. 8 the granite is seen in contact with a fine grained reddish aplite, which seems to be in the form of a dyke. The granite did not appear to be changed at the contact, but the other rock was finer grained. No. 682 shows this aplite ten feet from the contact, and No. 681 is the same from the contact. The shore was followed pretty closely in secs. 17, 18 and

19, T. 66-5, and many exposures were seen. No. 683, from the small island in the mouth of the bay which projects into the N. E. ¼ N. E. ¼ sec. 19, well represents the rock in sec. 17 and the S. E. ¼ of sec. 18. On the west side of the point in the extreme southeastern corner of N. E. ¼ S. E. ¼ sec. 18, the rock is decayed and the feldspar no longer shows distinct cleavage faces,—No. 684. Along the points in the S. W. ¼ S. E. ¼ sec. 18, the rock is much decayed and broken, but it still seems to be part of the granite,—No. 685. Just north of this, on the Canadian side and not more than two hundred feet distant, the ordinary granite similar to No. 683 is seen.

Outcrops of granite, similar to No. 683, continue along the east, south and west shores of the bay, which lies in the W. ½ of sec. 19, T. 66-5, almost to the west line of this section. At this line the rock is decayed, as shown by No. 687. On the Canadian side, just north of this, apparently the same rock is seen in a very schistose condition; it is also broken into well defined flagstones from one to four inches in thickness. These flagstones stand parallel to the schistosity, which strikes N. 40° W. and dips 70° towards the southwest. Similar rock, but with less schistose structure, is seen on the Minnesota side near this section line. The specimens collected from the Canadian side, Nos. 688 and 689, are not as full of large quartz grains as most of the rock here, but they are the soundest pieces that could be obtained. No. 689 is but a weathered condition of No. 688, as is shown by one of the specimens marked 689. It is not absolutely certain that this rock is part of the granite, but all indications seem to point that way. It is seen in many places in this vicinity and will be spoken of as altered granite.

Along the east shore of the bay in the S. E. ¼ sec. 24, T. 66-6, the rock is similar to Nos. 688 and 689, although sometimes of coarser grain. The rock along this shore in the E. ½ N. E. ¼ of the same quarter section is well represented by the last two numbers, by No. 690 and by Nos. 693 and 694, to be described below. In this subdivision of sec. 24 the altered granite is seen in contact with slates. There is, however, only a small mass of the slate in contact with this altered granite, but large amounts of it appear just to the south of this place. The contact is sharp and well defined. No. 691 shows the slate, which is a gray to a black argillyte No. 692 is the altered granite at the contact. These two specimens were taken within three inches of each other. The lamination and slaty cleavage of the slates are practically parallel, although the specimens collected (No. 691) do not show it. The strike is N. 34° W., and the dip is 68° towards S. 56° W. Rock No. 692 passes gradually into Nos. 693 and 694, and these three numbers were taken within a distance of four feet. No. 695 is from the slates about a foot from the contact; it is probably an interbedded band of graywacke. A small bed of slate, six inches wide, is seen with the altered granite on each side of it; this slate (No. 696) is very fissile and of a drab color, appearing considerably different from the ordinary slate (No. 691). The contact between the two rocks in both places is parallel to the strike of the slate, and the altered granite at the contact is finer grained, like Nos. 692 and 693, but grades off rapidly into a coarser grained facies, like No. 694. There seems to be no line between the ordinary granite (No. 683) and the rocks numbered 688, 689, 690, 692, 693 and 694, but there is a very evident line between the slates and these rocks. This altered granite is light gray or greenish gray in color when not weathered, but on weathering becomes brownish and seemingly coarser grained. This weathering in places does not extend more than a quarter of an inch into the rock, and in other places it goes as far as three inches from the surface; (compare specimens Nos. 688 and 689.)

On the east shore of the bay in the S. E. ¼ sec. 24, T. 66–6, just north of the little stream which flows from the lake to the south, the altered granite and slate are again seen in contact. Here there are three bands, three to six feet wide, of the altered granite, or what appears to be such, in the slate; the rock of these bands is shown by No. 727. This rock is sharply separated from the slates; in places it becomes coarse by the addition of large quartz grains. Just away from the contact are bands of grit in the slates like Nos. 729 and 730. Near the contact the slates hold bands, from one-half to six inches wide, of a fine grained graywacke (No. 728). It is hard to distinguish in some cases between the grit and the altered granite near the contact between this latter rock and the slates; almost the only difference to be seen is in the peculiar weathering, mentioned above, of the altered granite, but when this rock is in large masses it can be easily distinguished. The strike of the slates at this place varies from N. 90° W. to N. 20° W., and the dip from 70° to 80° towards the south. The lamination and slaty cleavage are parallel, but the rock has been much twisted. In some of the slaty beds there is a distinct schistose structure, which is different in direction from the slaty cleavage; this schistosity strikes from north and south to N. 5° E., and dips 70° to 80° towards the east. South of this little stream the dip and strike are rather constant; the latter is 75° towards S. 60° W., and the strike N. 30° W. Here was seen a bed of the grit, shown by No. 729, which held twisted fragments of slate. A little further south was another bed of the same, which had one side a very irregular line and one end was abruptly cut off by the slate. The grit from this place is shown by No. 730. The east shore of this bay was carefully examined south of the above mentioned stream. Many places were found where the grit held angular and twisted fragments of the slate. These fragments were in most cases entirely disconnected from the slaty bands and completely enclosed in the other rock. Nos. 731 and 732 are samples of the rock which held the slate fragments. In other places rock like this gradually passed into the slate. These bands of slates and grit continue along the south and west shore of this bay nearly to its north end, where the altered granite is again seen, at first holding beds of the slate. The phenomena here seem to be the same as described above. The strike of the slates was taken in several places; it averages N. 30° W., and the dip was 70° to 80° towards the southwest. However, there were some local variations in the strike; these varied from N. 20° W. to N. 45° W.

On the west shore of the bay in the W. ½ of sec. 19, T. 66–5, near the west line of this section, a series of specimens was collected representing the change from the granite to the so-called altered granite. These specimens were taken within a distance of fifteen feet; they are numbered from 717 to 725 inclusive. No. 720 seems to be only a decayed condition of No. 721. The exact order of the specimens to show the steps of this gradation is not certain, as the rock exposed was much broken into angular fragments, some of which were displaced a few inches. At this place the granite held one inclusion of a fine grained greenstone (No. 726).

At the portage from Saganaga west to Oak lake the altered granite is again seen, and also just west of this on the south shore of Oak lake. Here it holds small grains of white feldspar, No. 733. Farther west on the south shore the slates are seen holding bands of what appear to be the altered granite,—No. 734. Here the strike is N. 35° W., and the dip about 80° towards the southwest. The slate formation becomes well established before reaching the west end of Oak lake.

### *Wind lake and vicinity.*

This lake lies in the E. ½ E. ½ sec. 25, T. 66–6, and the W. ½ W. ½ sec. 30, T. 66–5, with a small bay projecting into the S. W. ¼ S. W. ¼ sec. 19, T. 66–5. It is connected with Saganaga lake by a small stream which flows from the north end of this small bay into the bay of Saganaga lake, which lies in the S. E. ¼ of sec. 24, T. 66–6.

On the west side of Wind lake, in the S. E. ¼ N. E. ¼ sec. 25, the rock is composed of intergrading and interbedded bands of a greenish slate (No. 697), a graywacke (No. 698) and a grit (No. 699). The banding and slaty cleavage coincide in direction. The strike is almost exactly north and south, and the dip is 75° to 82° towards the west. Back from the shore a hundred yards is a bluff composed mostly of graywacke and grit; here the general strike is north and south, although there is much local twisting. On the surface of the rock the glacial striæ are very distinct and run very nearly south. A short distance further south on the west shore, in the N. E. ¼ S. E. ¼ sec. 25, the rock at the shore appears almost massive and is broken up into angular blocks. There are many narrow bands, one to four inches wide, of slate in the rock, which strike N. 15° W. and dip W. 82°. The slate is laminated in places and is almost exactly similar to No. 691. The main mass of the rock varies from a graywacke, like No. 698, to a grit, like No. 699, and is very hard and compact. Frequently the slaty bands grade into the other rock. This exposure is at the north entrance to the little bay in the same $\frac{1}{16}$ section. At the west end and at the south entrance to this bay are exposures of the same rock, but with fewer slaty bands. The strike is rather imperfectly shown, but seems to be N. 20° W. No. 700 is the graywacke from the west side of this bay; it somewhat resembles some facies of the altered granite found in contact with the slate on Saganaga lake. South of this bay no exposures are seen on the west shore, and there are none on the south shore. On the east shore near the south end of the lake, and back a few yards from the water, is a large exposure of the graywacke, in which the lamination is indistinct. On the southwest side of this exposure of graywacke is an area of black to gray slate about eight feet wide and twenty-five feet long, and exposed for six to seven feet in hight. The slaty cleavage is distinct, striking N. 50° W. and dipping 85° S.W. The lamination is extremely distinct; it has the same strike but dips 52° towards the northeast. This lamination fades out gradually into the graywacke. The slate is to all appearances the same as that seen on the west side of the lake. No. 701 shows in a small way this discordance of slaty cleavage and lamination. This exposure is in the S. E. ¼ S. W. ¼ S. W. ¼ sec. 30, T. 66–5.

Several outcrops of rock varying from slate to graywacke occur on the east shore in S. W. ¼ sec. 30. The slaty cleavage and the lamination, where seen, always coincide. The strike on the little point in the W. ½ N. W. ¼ S. W. ¼ sec. 30 is N. 5° W. and the dip is 70° W. The little island just off the point in the S. W. ¼ N.

W. ¼ sec. 30 has a fine exposure. Here the bedding of the graywacke is seen to good advantage; strike N. 22° W. and dip 70° towards S. 68° W. On the point at the west entrance to the bay in E. ½ S. W. ¼ N. W. ¼ sec. 30 the strike is N. 22° W. and the dip 70° to 76° towards S. 68° W. The shores of this bay are low and show no outcrops, but on the shore about 300 feet east of the last named point is an outcrop of altered granite like No. 689. It is roughly schistose; this structure is vertical and runs north and south. Less than fifty yards east of this is a ridge of the same rock very coarse grained. A little further north (in the E. ½ N. W. ¼ sec. 30) the rock at the shore is the same as in the ridge. In places four-fifths of the rock is composed of quartz as is shown by No. 702. Apparently in this altered granite was a small, illy exposed area of brownish fissile slate. No. 703 shows this slate and No. 704 a condition of it near the ordinary altered granite. It appears as if this slate is part of the slate formation of the region enclosed in the other rock, but nothing definite could be made out concerning it.

The altered granite extends along the east shore in the N. W. ¼ sec. 30, and to the extreme northern point of the lake. Here, on the east side of the stream which flows into Saganaga lake, the rock is altered granite, but on the west side of this stream the slate and graywacke formation appears. The slates hold bands of what seem to be the altered granite, and also of graywacke and grit. It is here impossible to distinguish between these rocks, in fact it seems as if the so-called altered granite was a part of the grit and graywacke. Nos. 705, 706 and 707, from the east end of this exposure, show facies of the altered granite or of the grit and graywacke. No. 708 certainly seems to be grit; it was taken over fifty yards from the main mass of the altered granite. In one place one of these questionable bands was seen to hold fragments of slate near its edge,—No. 709. In no place did I see any of the so-called altered granite bands cutting across the strike of the slates. Nearest the main mass of altered granite the slates are brownish, as those found inclosed in the other rock (see Nos. 704 and 705) and are shown by No. 710.

The slaty formation extends along the north and west shores of of Wind lake. Northwest from the northwest corner of the lake is a high bluff composed mostly of grit and graywacke, the former apparently somewhat re-crystallized (No. 711). Here the dip is 75° to 80° towards S. 60° W. About a quarter of a mile south of this bluff the dip is 80° towards S. 70° W.

On going east from the south end of the lake to the small lake which is crossed by the south line of sec. 30, east of the quarter post, only a few outcrops were seen. These were of the same slate formation as exists on the shores of Wind lake. On the west shore of this small lake the strike is N. 20° W. and the dip 80° towards S. 70° W., but at an outcrop about an eighth of a mile west of this the strike is N. 25° E. and the dip is probably 80° towards N. 65° W., but the dip could not be accurately determined, as only a smooth glaciated surface was exposed. An outcrop on the east shore of this small lake appears to be of the same slaty formation, but it was not visited. In the E. ½ of N. W. ¼ sec. 30, the altered granite similar to No. 702 is seen.

South of Wind lake a short distance are a few outcrops of the slate formation. Here the beds are twisted somewhat, but the general strike is a little west of north. Southeast from the lake the slate outcrops extend for a quarter of a mile. The dip taken on one outcrop was vertical and the strike N. 25° W. We went east-southeast from the southeast end of Wind lake, but after passing the above mentioned outcrops of slate no other rock was seen *in situ* until coming into about the N. E. ¼ S. W. ¼ sec. 32, T. 66–5. Here the ordinary coarse grained hornblende granite occurs, but of not quite as coarse grain as that usually seen on Saganaga lake. Farther on, probably in the S. W. ¼ S. E. ¼ of the same section, granite is again seen.

On going east from Wind lake about the centre of the N. W. ¼ sec. 30, an apparent gradation is seen between the altered granite and the ordinary granite. The latter was found in the midst of the former and not separated from it by any line or sudden change. Nos. 712 to 716, together with the finer grained conditions of this rock already described, show this gradation into the ordinary granite. In its coarsest condition the altered granite is much weathered and decayed, and it is difficult to get good specimens of it. I also went east from the lake a short distance on the north line of sec. 30, and then northeast to the bay of Saganaga lake in the S. W. ¼ sec. 19, T. 66–5, and saw essentially the same gradations. In places the altered granite has irregular areas in which the large quartz grains are lacking and the rock is almost entirely composed of a fine greenish material, as seen in specimens Nos. 688 and 689. In a few places the large quartz grains were arranged along definite, distinct lines or "beds," and this arrangement faded off into the main mass of the rock where no arrangement of the grains could be seen. These "beds" ran from 10° to 30° W. of N. and seemed to stand vertical.

## PART II.—CATALOGUE OF ROCK SPECIMENS

### COLLECTED BY ULYSSES SHERMAN GRANT IN 1891.

This is a continuation of the list ended on page 215 of the 17th (1888) Annual Report. The page references refer to the places where the specimens are described in this report.

### KAWISHIWI RIVER AREA.

299. Greenstone. Just south of Pickerel lake, on the east line of sec. 25, T. 63–11. P. 39.

300. Quartzless porphyry. A short distance south of the last. P. 39.

301. Contact of the last with the greenstone. Same locality. P. 39.

302. Greenstone. S. E. ¼ N. W. ¼ sec. 25, T. 63–11, portage from Kawishiwi river to Pickerel lake. P. 39.

303. Schistose graywacke. Same locality. P. 39.

304. Greenstone. S. E. ¼ N. W. ¼ sec. 25, T. 63–11, Pickerel lake. P. 39.

305. Greenstone. N. W. ¼ N. E. ¼ sec. 25, T. 63–11, south shore of Pickerel lake. P. 39.

306. Siliceous greenstone. N. W. ¼ N. E. ¼ sec. 25, T. 63–11, south shore of Pickerel lake. P. 39.

307. Greenstone. N. E. ¼ N. W. ¼ sec. 30, T. 63–10, south shore of Pickerel lake, at the outlet. P. 39.

308. Greenstone. N. E. ¼ N. W. ¼ sec. 30, T. 63–10, east end of Pickerel lake. P. 39.

309. Greenstone. S. W. ¼ S. W. ¼ sec. 19, T. 63–10, north shore of Pickerel lake. P. 39.

310. Sericitic schist. East line of sec. 19, T. 63–11, north of the quarter post. P. 39.

311. Coarse gneissic syenite. A short distance farther south and just north of the quarter post. P. 39.

312. Fine granite. Same locality. P. 39.

313. Dark gneissic syenite. East line of sec. 19, T. 63–11, south of the quarter post. P. 39.

314. Mica-schist. Same locality. P. 39.

315. Fine biotite granite vein rock. Same locality. P. 40.

316. Mica-schist. S. W. ¼ N. W. ¼ sec. 30, T. 63–10, little point on north side of the Kawishiwi river. P. 40.

317. Fine vein granite. Same locality. P. 40.

318. Mica-schist. South of the Kawishiwi river, about on the west line of sec. 31, T. 63–10. P. 43.

319. Green schist. Same locality. P. 43.

320. Red syenite. N. E. ¼ S. W. ¼ sec. 30, T. 63–10, south shore of the Kawishiwi river. P. 43.

321. Dyke rock in the syenite. Same locality. P. 44.

322 to 325. Syenite near the contact with the mica-schist. Same locality. P. 44.

326 to 328. Mica-schist near the contact with the syenite. Same locality. P. 44.

329. Syenite and mica-schist in contact; not *in situ*. Same locality. P. 44.

330. Fine diorite dyke rock. S. W. ¼ N. E. ¼ sec. 30, T. 63–10. P. 44.

331. Hornblende gneiss; inclusion in syenite. Same locality. P. 44.

332. Siliceous schist; inclusion in syenite. Same locality. P. 44.

333 to 336. Specimens showing change from mica-schist to syenite. S. E. ¼ N. E. ¼ sec. 30, T. 63–10, east shore of Kawishiwi river. P. 44.

337. Syenite showing "flowage structure." S. W. ¼ N. W. ¼ sec. 32, T. 63–10, south shore of Clearwater lake. P. 40.

338. Red syenite. Same locality. P. 40.

339. Coarse syenite. S. W. ¼ S. E. ¼ sec. 29, T. 63–10, north shore of Clearwater lake. P. 40.

340. Fine syenite. West line of sec. 32, T. 63–10, north shore of Clearwater lake. P. 41.

341. Mica-schist and syenite in contact. N. E. ¼ N. E. ¼ sec. 31, T. 63–10, north shore of Clearwater lake. P. 41.

342. Red syenite near contact with mica-schist. Same locality. P. 42.

343. Coarse black diorite. E. ½ N. E. ¼ sec. 31, T. 63–10, west shore of Clearwater lake. P. 41.

344. Red syenite cutting the above diorite. Same locality. P. 41.

345. Gray syenite cutting the above diorite. Same locality. P. 41.

346. Trap dyke rock. Same locality. P. 41.

347 and 348. Red syenite. West line of sec. 5, T. 62–10, north of the Kawishiwi river. P. 41.

349. Hornblende vein rock. Same locality. P. 41.

350. Dark red syenite. Near the west line of sec. 5, T. 62–10, north shore of the Kawishiwi river. P. 42.

351. Dark coarse syenite. Same locality. P. 42.

352 to 354. Coarse dark diorite. S. W. ¼ N. W. ¼ sec. 5, T. 62–10, north shore of the Kawishiwi river. P. 42.

355. Syenite. S. E. ¼ N. E. ¼ sec. 5, T. 62–10, Kawishiwi river. P. 42.

356. Red hornblende granite. N. W. ¼ S. W. ¼ sec. 9, T. 62–10, south shore of the Kawishiwi river. P. 42.

357. Gabbro. S. W. ¼ S. W. ¼ sec. 9, T. 62–10. P. 42.

358. Fine grained biotite granite. Same locality. P. 42.

359. Biotite syenite. Same locality. P. 42.

360. Red aplite. Same locality. P. 42.

361. Fine micaceous syenite. S. W. ¼ sec. 9, T. 62–10, east shore of the Kawishiwi river. P. 42.

362. Fine gray syenite. Same locality. P. 42.

363 and 364. Intermediate between gabbro and syenite. Same locality. P. 42.

365. Purple porphyrite (?). Same locality. P. 43.

366. Dark syenite. Sec. 34 (?), T. 63–10, west shore of the Kawishiwi river. P. 43.

367. Syenite. Same locality. P. 43.

368. Coarse syenite. S. W. ¼ sec. 34, T. 63–10, west shore of the Kawishiwi river. P. 43.

369. Coarse diorite. Just north of the centre of sec. 26, T. 63–10, south shore of the Kawishiwi river. Pp. 44–45.

370. Trap dyke rock. Same locality. P. 45.

371. Fine red granite. Same locality. P. 45.

372. Fine gray granite. Just west of the last. P. 45.

373. Diorite. Same locality. P. 45.

374. Diorite and granite in contact. Same locality. P. 45.

375. Coarse diorite. S. W. ¼ sec. 26, south shore of the Kawishiwi river. P. 45.

376. Diorite, fine grained. N. W. ¼ S. W. ¼ sec. 26, T. 63–10, south shore of the Kawishiwi river. P. 45.

377. Coarse red syenite. S. W. ¼ S. W. ¼ sec. 26, T. 63–10, south shore of the Kawishiwi river. P. 45.

378. Gneiss inclusion in the syenite. Same locality. P. 45.

379. Greenstone. West line of sec. 22, T. 63–10, north of the Kawishiwi river. P. 45.

380. Greenstone. Same locality. P. 45.

381. Quartz porphyry. Same locality. P. 45.

382. Greenstone. West line of sec. 22, T. 63–10, ¾ mile north of the Kawishiwi river. P. 46.

383. Fine graywacke. N. E. ¼ N. E. ¼ sec. 28, T. 63–10, north shore of the Kawishiwi river. P. 46.

384. Coarser graywacke. Same locality. P. 46.

385. Coarse graywacke. N. E. ¼ N. E. ¼ sec. 28, T. 63–10, north shore of the Kawishiwi river. P. 46.

386. Finer graywacke; Same locality. P. 46.

387. Gneissic syenite. N. E. ¼ N. E. ¼ sec. 28, T. 63–10, portage along north side of the Kawishiwi river. P. 46.

388. Fissile greenstone. N. W. ¼ N. E. ½ sec. 28, T. 63–10, portage along north side of the Kawishiwi river. P. 46.

389 to 394. Specimens illustrating passage from greenstone to syenite. Same locality. P. 47.

395. Finely jointed greenstone. Same locality. P. 47.

395A. Sericitic graywacke. N. E. ¼ N. W. ¼ sec. 28, T. 63–10, portage along the north side of the Kawishiwi river. P. 47.

396. Contact of graywacke and syenite. Same locality. P. 47.

397 to 400. Facies of the syenite near the contact. Same locality. P. 47.

401. Greenstone. Same locality. P. 47.

402. Quartz porphyry from edge of dyke. N. ½ N. W. ¼ sec. 28, T. 63–10, north shore of the Kawishiwi river. P. 48.

403. The same from center of dyke, Same locality. P. 48.

404. Gray gniess. S. E. ¼ N. W. ¼ sec. 28, T. 63–10, south of the Kawishiwi river. P. 48.

405. Sericitic schist. Same locality. P. 49.

406 to 408. Gray gneiss. Same locality. P. 49.

409. Diorite in the gneiss. Same locality. P. 49.

410. Red syenite. N. E. ¼ N. E. ¼ sec. 29, T. 63–10, north shore of the Kawishiwi river. P. 49.

411. Quartzporphyry. N. ½ N. E. ¼ sec, 29, T. 63–10, north shore of the Kawishiwi river. P. 49.

412. Greenstone. West line of sec. 21, T. 63–10, one-eighth mile north of the S. W. corner of this section. P. 56.

413. Gray granite porphyry. N. W. ¼ S. E. ¼ sec. 20, T. 63–10, west shore of lake. P. 56.

414. Quartzporphyry (?). N. W. ¼ N. E. ¼ sec. 21, T. 63–10, north shore of lake. P. 56.

415. Greenstone near dyke walls. N. ½ N. E. ¼ sec. 21, T. 63–10, south shore of lake. P. 57.

416. Quartz porphyry at edge of dyke. Same locality. P. 57.

417. The same from center of dyke. Same locality. P. 57.

418. Greenstone. South line of sec. 16, T. 63–10, north shore of lake. P. 57.

419. Magnetite slate. East line of sec. 16, T. 63–10, a short distance north of the quarter post. P. 58.

420 to 422. Sericitic gneiss near syenite contact. Near the west line of sec. 28, T 63–10, one-third mile south of the Kawishiwi river. P. 50.

423. Gneiss and syenite in contact. Same locality. P. 50.

424. Gneissic syenite near the contact with the gneiss. Same locality. P. 50.

425. Red syenite. Same locality. P. 50.

426. Sericitic schist. Near the west line of sec. 29, T. 63–10, south of the Kawishiwi river. P. 50.

427. Mica-schist. Same locality. P. 50.

428. Syenite porphyry (?). N. ½ N. W. ¼ sec. 29, T. 63–10, north of the Kawishiwi river. P. 51.

429 to 431. Gray gneiss. Small island in the bay in the N. W. ¼ N. W. ¼ sec. 27, T. 63–10, Kawishiwi river. P. 51.

432. Reddish syenite. Same locality. P. 51.

433. Schist inclusion in syenite. Same locality. P. 51.

434. Mica-schist from inclusion in syenite. East shore of the same bay. P. 51.

435 Mica-schist and syenite in contact. Same locality. P. 51.

436. Schistose syenite. S. E. corner of bay in N. E. ¼ N. W. ¼ sec 27, T. 63–10, Kawishiwi river. P. 51.

437. Gneissic syenite (?). Same locality. P. 51.

438. Gneiss. Same locality. P. 51.

439. Granite vein rock. Same locality. P. 52.

440. Schistose syenite. N. ½ sec. 27, T. 63–10, north shore of the Kawishiwi river. P. 52.

441. Chloritic syenite. Same locality. P. 52.

442. Dark gneiss. N. E. ¼ N. E. ¼ sec. 27, T. 63–10, north shore of the Kawishiwi river. P. 53.

443 and 444. Sericitic gneiss. N. W. ¼ N. W. ¼ N. W. ¼ sec. 26, T. 63–10, north shore of the Kawishiwi river. P. 53.

445. Gray hornblende gneiss. Same locality. P. 53.

446. Gneiss and green inclusion. Same locality. P. 53.

447. Mica-schist. N. W. ¼ N. W. ¼ sec. 26, T. 63–10, north shore of the Kawishiwi river. P. 53.

448. Greenstone inclusion in syenite. N. W. ¼ N. W. ¼ sec. 26, T. 63–10, north of the Kawishiwi river. P. 54.

shown by No. 654 to a fine grained green facies shown by No. 659. Bands of the matrix free from pebbles are common, and in such cases the rock is occasionally laminated. The strike at a place 100 yards east of the granite bands is N. 10° E., but near these bands it varies from N. 10° W. to exact N. and S.; the dip in all cases is vertical.

The granite is again seen on the northeastern side of the round point in the S. W. ¼ of S. W. ¼ of N. W. ¼ sec. 8, and also on the point just east of this. At the southwest corner of the bay, which runs into the S. E. ¼ of N. E. ¼ sec. 7, is a green rock similar to No. 651; it is cut by the granite and is also seen in sharp contact with a fine grained purplish porphyritic rock, which seems to be in the form of a dyke, although this could not be definitely seen. This porphyritic rock is the same as Nos. 660 and 661. On the northwest shore of this bay is a ridge of granite. Granite is also seen in several places on the north shore of the bay, and in one place is in contact with a purplish rock, which is much decayed and resembles a porphyrite. The line between this rock and the granite is very distinct, and the former seems to cut the latter in the form of a dyke. The granite is unchanged at the contact, but the other rock here seems to be finer grained than usual. No. 660 shows this porphyrite (?) from the contact, and No. 661 is the same twenty feet from the granite.

Along the west shore of the lake the granite is seen in several outcrops in the N. E. ¼ of N. W. ¼ sec. 8 and S. W. ¼ sec. 5. Near the end of the point in the N. E. ¼ S. W. ¼ sec. 8 is a diabase dyke in the granite. This dyke is also seen in the bay on the west of this point. No. 662 represents the diabase of this dyke; it is finer grained near the edge. The same dyke is also seen on the west and east sides of the end of the point in the N. ½ of S. E. ¼ sec. 5. It has an east and west direction and varies from thirty to forty feet in width. On going west from the southwest side of the bay in the N. W. ¼ S. W. ¼ sec. 5 the same dyke is again seen in contact with the granite, and both rocks form a ridge that runs west from the lake for an eighth of a mile. Beyond this (west) is a swamp with no exposures, and then not less than a quarter of a mile from the lake is a ridge running northeast and southwest. This ridge is made of a fine grained laminated slate (No. 665), which varies from a gray to a green argillyte. The lamination and slaty structure coincide and strike N. 15° E. and stand vertical. South of this ridge a few rods is another composed of a green to gray grit (No. 664), which is like the matrix of the conglomerate above described—Nos. 654 and 659. No pebbles are visible in this rock, nor is there any lamination, but in it are a few narrow bands of slate similar to No. 663. These stand vertical and strike N. 30° E.

The granite is seen in several outcrops on the shores of the bay in the centre of the N. ½ sec. 5, and also on the point on the east side of this bay. The east shore of the point in the S. E. ¼ S. E. ¼ sec. 8 was also examined and found to be composed of granite.

The granite of West Sea Gull lake varies considerably in grain and also in the amount of chlorite or hornblende present. The fresh rock is a hornblende granite, but in many places this has been completely changed to chlorite. There seem to be two feldspars present,—a yellow and a pink one. No. 675 is as fresh as any of the granite of this lake and may be taken as a typical example of it. This specimen was taken from the east side of an island in the S. W. ¼ S. E. ¼ sec. 8.

### *Small lake in the N. W. ¼ of N. W. ¼ of sec. 8, T. 65-5.*

This lake is not shown on the government plat. On the east and north shores of the lake no rock exposures were seen. On the west shore near the north end is a ridge composed of the Ogishke conglomerate similar in every respect to that described from West Sea Gull lake in this same section. The conglomerate was traced west over the ridge for a short distance; the pebbles became fewer in number and the rock in places was slaty, almost exactly like No. 663. At one place the slaty rock was crumpled as if it had been pressed in a direction parallel to the strike; this was seen for only a short distance. In places the matrix showed a lamination and again it was broken into long flags. The lamination, the long direction of the flags and the banding and slaty cleavage of the slaty areas were all parallel and stood vertical; the dip was N. 15° E.

On the west side of the lake near the south end the granite is seen at the shore. It is chloritic and holds large quartz grains and reddish feldspars,—No. 665. The conglomerate is seen not more than an eighth of a mile west of the shore, but the junction of it and the granite was not found. What is said about the conglomerate in the last paragraph will apply equally well here, except that the strike is N. 20° E. Back from the shore the granite becomes schistose in places; this schistose structure stands vertical and strikes N. 20° E. Here the rock is similar to No. 665, excepting for this schistosity. A little further west the granite has changed to a yellow rock holding large quartz grains,—No. 666.

This and the conglomerate were separated by several yards of soil where there was but one exposure. This exposure is within twenty feet of the conglomerate; the rock is shown by No. 667, which appears to be a more decayed part of the granite. On the west side of this exposure there seems to be, although this could not be distinctly made out, an interbanding of rock similar to No. 667 and a rock similar to this, but finer grained and greener. It is, however, possible that this last is but a less weathered condition of the former, and that they are both decayed conditions of the granite. The two rocks (if there are two) are shown by No. 668. Twenty feet west of this is the conglomerate with the matrix like No. 664.

No other rock exposures occur on this lake, but between its southeast corner and West Sea Gull lake is a knoll of the ordinary granite.

### *Small lake in the S. ½ of N. W. ¼ of sec. 16, T. 65-5.*

From the foot of the bay of West Sea Gull lake, in which are the corners of secs. 8, 9, 16 and 17, a portage leads south to this small lake. The ordinary granite is seen in two or three places on and near this portage trail. Granite also occurs where the west line of sec. 16 cuts the north shore of the little bay that projects into the S. E. ¼ N. E. ¼ sec. 17, and also a short distance on either side of this line. On the west side of this little bay is a rounded hill, the northern part of which is composed of granite and the southern part of a hardened mica-schist (No. 669), which in places looks almost like a fine diabase. The granite is in sharp contact with this rock and cuts it with many vein-like forms. These veins are like the granite elsewhere and differ only in being finer grained in places. The whole exposure much resembles that seen in the N. W. ¼ N. E. ¼ sec. 17, West Sea Gull lake, and described under Nos. 647 to 650.

Back from the shore at the southwest corner of this little bay the same hardened mica-schist is seen, and it occurs again within a few feet of where the west line of sec. 16 cuts the south shore of this bay. Continuing along the southwestern shore of the lake more of the hardened mica-schist is seen; it varies to a green slaty rock and also to a green siliceous schist (No. 670). These were all cut by granite veins. On the south shore near the east end of the lake the granite is seen in a large outcrop. No outcrops were seen on the north shore of this lake excepting on the little point in the centre of the N. ½ S. W. ¼ N. W. ¼ sec. 16, and on the small island just off this point; here the rock was granite.

A small stream flows from this lake east to Sea Gull lake, in the S. E. ¼ N. W. ¼ sec. 16, and just south of the stream is a short portage between the two lakes. Granite occurs a few feet south of this portage.

### *Sea Gull lake.*

The western shore of this lake, in sec. 16, T. 65–5, was rather carefully examined. There were many exposures, but these were all granite except on the south side of the bay in the N. E. ¼ S. E. ¼ sec. 16, and on the shore in the S. E. ¼ S. E. ¼ sec. 16. Here were outcrops of the same hardened mica-schist, varying to a green slaty rock, as described above. (Compare Nos. 669 and 670.)

Where the east line of sec. 16 cuts the south shore the granite is seen; here it is chloritic, rather decayed and somewhat schistose, —No. 671. Back from the shore a few rods and just west of the section line is a ridge of fine grained mica-schist, varying to chloritic schist. Farther south and on the north side of the east and west ridge, on which is the southeastern corner of sec. 16, is a small amount of fine grained granite (No. 672), probably a stringer from the main granite mass. The south side of this ridge is made up of a greenish mica-schist (No. 673); here the strike of the schistose structure is N. 70° W. and the dip is vertical. A short distance further south is another ridge of the same rock. No lamination was seen in this schist; it varies from a fine mica-schist, like No. 673, to rock similar to Nos. 651 and 670. On this last ridge is a small amount of a gray quartz porphyry in the schists; this appeared like a band running parallel with the schists;—No. 674.

### *Red Rock lake.*

The outcrops on the west end of the bay that projects into the N. E. ¼ N. E. ¼ sec. 5, T. 65–5, are all granite. The bay which lies in the E. ½ N. E. ¼ sec. 32 and W. ½ N. W. ¼ sec. 33, T. 66-5, was examined. Here there are several outcrops of the ordinary granite.

On going north from West Sea Gull lake the granite becomes coarser in grain and more pink in color; it is hornblendic rather than chloritic. The quartz grains are especially large,—commonly a quarter of an inch across and sometimes as much as half an inch. Frequently one-third of the rock is made up of these large quartz grains.

### *Saganaga lake.*

The coarse grained granite of Red Rock lake is found also on Saganaga lake. No. 686 from the point in the S. W. ¼ N. E. ¼ sec. [illegible] T. 66–5, fairly represents the granite of the main part of Sag-

anaga lake. It is of decidedly coarse grain and of a pinkish color. The large irregular areas of quartz are very noticeable. The feldspar is pinkish and sometimes yellowish. Hornblende is present in considerable amount and is more or less changed to chlorite.

On the east end of a long island which lies just south of the point in the S. W. ¼ N. E. ¼ sec. 22, T. 66–5, is a a diabase dyke in the granite. This dyke is ten feet in width and has a north and south direction.

The island which lies mostly in the S. E. ¼ N. W. ¼ sec. 14, T. 66–5, is composed of a rock which varies from a fine grained syenite, made up almost completely of feldspar and very little hornblende, to a very coarse grained syenite of the same kind, and again to a rock composed mostly of feldspar and quartz, the latter in very large grains. In places it is porphyritic and has a reddish feldspathic ground-mass, in which are red feldspar crystals and sometimes quartz crystals. Disseminated through the rock in veins, and also in small grains, is a dark violet fluor spar. There are also some few small yellow grains in the rock which resemble talc. At the north side of this island is a large mass of white quartz which extends along the shore for over a hundred feet. This quartz mass was not seen in other places on the island. Mixed in with the quartz are fluor spar, yellow talc and red feldspar; the latter often shows cleavage faces eight or ten inches across. Small quartz crystals are seen in cavities; these crystals vary from colorless ones to those that are purple and even black. The rock from this island is represented by Nos. 676, 677 and 678.

In the N. E. ¼ N. W. ¼ sec. 14, T. 66–5, south side of the large island crossed by the north line of this section, the rock appears to be porphyritic with large quartzes; this is probably a decayed condition of the ordinary granite, the quartz being the only mineral unaltered. This rock is represented by Nos. 679 and 680. This rock is seen further east in the same $\frac{1}{16}$ section along the shore of the island. In the S. W. ¼ S. E. ¼ sec. 11, the ordinary granite occurs, and this is also seen in several places in the S. ½ of sec. 11, on the west shore of this large island.

All the outcrops seen along the shore in secs. 10 and 9, T. 66-5, were of the usual coarse grained granite. On the little island in the extreme southeast corner of sec. 8 the granite is seen in contact with a fine grained reddish aplite, which seems to be in the form of a dyke. The granite did not appear to be changed at the contact, but the other rock was finer grained. No. 682 shows this aplite ten feet from the contact, and No. 681 is the same from the contact. The shore was followed pretty closely in secs. 17, 18 and

19, T. 66-5, and many exposures were seen. No. 683, from the small island in the mouth of the bay which projects into the N. E. ¼ N. E. ¼ sec. 19, well represents the rock in sec. 17 and the S. E. ¼ of sec. 18. On the west side of the point in the extreme southeastern corner of N. E. ¼ S. E. ¼ sec. 18, the rock is decayed and the feldspar no longer shows distinct cleavage faces,—No. 684. Along the points in the S. W. ¼ S. E. ¼ sec. 18, the rock is much decayed and broken, but it still seems to be part of the granite,—No. 685. Just north of this, on the Canadian side and not more than two hundred feet distant, the ordinary granite similar to No. 683 is seen.

Outcrops of granite, similar to No. 683, continue along the east, south and west shores of the bay, which lies in the W. ½ of sec. 19, T. 66-5, almost to the west line of this section. At this line the rock is decayed, as shown by No. 687. On the Canadian side, just north of this, apparently the same rock is seen in a very schistose condition; it is also broken into well defined flagstones from one to four inches in thickness. These flagstones stand parallel to the schistosity, which strikes N. 40° W. and dips 70° towards the southwest. Similar rock, but with less schistose structure, is seen on the Minnesota side near this section line. The specimens collected from the Canadian side, Nos. 688 and 689, are not as full of large quartz grains as most of the rock here, but they are the soundest pieces that could be obtained. No. 689 is but a weathered condition of No. 688, as is shown by one of the specimens marked 689. It is not absolutely certain that this rock is part of the granite, but all indications seem to point that way. It is seen in many places in this vicinity and will be spoken of as altered granite.

Along the east shore of the bay in the S. E. ¼ sec. 24, T. 66-6, the rock is similar to Nos. 688 and 689, although sometimes of coarser grain. The rock along this shore in the E. ½ N. E. ¼ of the same quarter section is well represented by the last two numbers, by No. 690 and by Nos. 693 and 694, to be described below. In this subdivision of sec. 24 the altered granite is seen in contact with slates. There is, however, only a small mass of the slate in contact with this altered granite, but large amounts of it appear just to the south of this place. The contact is sharp and well defined. No. 691 shows the slate, which is a gray to a black argillyte No. 692 is the altered granite at the contact. These two specimens were taken within three inches of each other. The lamination and slaty cleavage of the slates are practically parallel, although the specimens collected (No. 691) do not show it. The strike is N. 34° W., and the dip is 68° towards S. 56° W. Rock No. 692 passes gradually into Nos. 693 and 694, and these three numbers were taken within a distance of four feet. No. 695 is from the slates about a foot from the contact; it is probably an interbedded band of graywacke. A small bed of slate, six inches wide, is seen with the altered granite on each side of it; this slate (No. 696) is very fissile and of a drab color, appearing considerably different from the ordinary slate (No. 691). The contact between the two rocks in both places is parallel to the strike of the slate, and the altered granite at the contact is finer grained, like Nos. 692 and 693, but grades off rapidly into a coarser grained facies, like No. 694. There seems to be no line between the ordinary granite (No. 683) and the rocks numbered 688, 689, 690, 692, 693 and 694, but there is a very evident line between the slates and these rocks. This altered granite is light gray or greenish gray in color when not weathered, but on weathering becomes brownish and seemingly coarser grained. This weathering in places does not extend more than a quarter of an inch into the rock, and in other places it goes as far as three inches from the surface; (compare specimens Nos. 688 and 689.)

On the east shore of the bay in the S. E. ¼ sec. 24, T. 66–6, just north of the little stream which flows from the lake to the south, the altered granite and slate are again seen in contact. Here there are three bands, three to six feet wide, of the altered granite, or what appears to be such, in the slate; the rock of these bands is shown by No. 727. This rock is sharply separated from the slates; in places it becomes coarse by the addition of large quartz grains. Just away from the contact are bands of grit in the slates like Nos. 729 and 730. Near the contact the slates hold bands, from one-half to six inches wide, of a fine grained graywacke (No. 728). It is hard to distinguish in some cases between the grit and the altered granite near the contact between this latter rock and the slates; almost the only difference to be seen is in the peculiar weathering, mentioned above, of the altered granite, but when this rock is in large masses it can be easily distinguished. The strike of the slates at this place varies from N. 90° W. to N. 20° W., and the dip from 70° to 80° towards the south. The lamination and slaty cleavage are parallel, but the rock has been much twisted. In some of the slaty beds there is a distinct schistose structure, which is different in direction from the slaty cleavage; this schistosity strikes from north and south to N. 5° E., and dips 70° to 80° towards the east. South of this little stream the dip and strike are rather constant; the latter is 75° towards S. 60° W., and the strike N. 30° W. Here was seen a bed of the grit, shown by No. 729, which held twisted fragments of slate. A little further south was another bed of the same, which had one side a very irregular line and one end was abruptly cut off by the slate. The grit from this place is shown by No. 730. The east shore of this bay was carefully examined south of the above mentioned stream. Many places were found where the grit held angular and twisted fragments of the slate. These fragments were in most cases entirely disconnected from the slaty bands and completely enclosed in the other rock. Nos. 731 and 732 are samples of the rock which held the slate fragments. In other places rock like this gradually passed into the slate. These bands of slates and grit continue along the south and west shore of this bay nearly to its north end, where the altered granite is again seen, at first holding beds of the slate. The phenomena here seem to be the same as described above. The strike of the slates was taken in several places; it averages N. 30° W., and the dip was 70° to 80° towards the southwest. However, there were some local variations in the strike; these varied from N. 20° W. to N. 45° W.

On the west shore of the bay in the W. ½ of sec. 19, T. 66–5, near the west line of this section, a series of specimens was collected representing the change from the granite to the so-called altered granite. These specimens were taken within a distance of fifteen feet; they are numbered from 717 to 725 inclusive. No. 720 seems to be only a decayed condition of No. 721. The exact order of the specimens to show the steps of this gradation is not certain, as the rock exposed was much broken into angular fragments, some of which were displaced a few inches. At this place the granite held one inclusion of a fine grained greenstone (No. 726).

At the portage from Saganaga west to Oak lake the altered granite is again seen, and also just west of this on the south shore of Oak lake. Here it holds small grains of white feldspar, No. 733. Farther west on the south shore the slates are seen holding bands of what appear to be the altered granite,—No. 734. Here the strike is N. 35° W., and the dip about 80° towards the southwest. The slate formation becomes well established before reaching the west end of Oak lake.

### *Wind lake and vicinity.*

This lake lies in the E. ½ E. ½ sec. 25, T. 66–6, and the W. ½ W. ½ sec. 30, T. 66–5, with a small bay projecting into the S. W. ¼ S. W. ¼ sec. 19, T. 66–5. It is connected with Saganaga lake by a small stream which flows from the north end of this small bay into the bay of Saganaga lake, which lies in the S. E. ¼ of sec. 24, T. 66–6.

On the west side of Wind lake, in the S. E. ¼ N. E. ¼ sec. 25, the rock is composed of intergrading and interbedded bands of a greenish slate (No. 697), a graywacke (No. 698) and a grit (No. 699). The banding and slaty cleavage coincide in direction. The strike is almost exactly north and south, and the dip is 75° to 82° towards the west. Back from the shore a hundred yards is a bluff composed mostly of graywacke and grit; here the general strike is north and south, although there is much local twisting. On the surface of the rock the glacial striæ are very distinct and run very nearly south. A short distance further south on the west shore, in the N. E. ¼ S. E. ¼ sec. 25, the rock at the shore appears almost massive and is broken up into angular blocks. There are many narrow bands, one to four inches wide, of slate in the rock, which strike N. 15° W. and dip W. 82°. The slate is laminated in places and is almost exactly similar to No. 691. The main mass of the rock varies from a graywacke, like No. 698, to a grit, like No. 699, and is very hard and compact. Frequently the slaty bands grade into the other rock. This exposure is at the north entrance to the little bay in the same $\frac{1}{16}$ section. At the west end and at the south entrance to this bay are exposures of the same rock, but with fewer slaty bands. The strike is rather imperfectly shown, but seems to be N. 20° W. No. 700 is the graywacke from the west side of this bay; it somewhat resembles some facies of the altered granite found in contact with the slate on Saganaga lake. South of this bay no exposures are seen on the west shore, and there are none on the south shore. On the east shore near the south end of the lake, and back a few yards from the water, is a large exposure of the graywacke, in which the lamination is indistinct. On the southwest side of this exposure of graywacke is an area of black to gray slate about eight feet wide and twenty-five feet long, and exposed for six to seven feet in hight. The slaty cleavage is distinct, striking N. 50° W. and dipping 85° S.W. The lamination is extremely distinct; it has the same strike but dips 52° towards the northeast. This lamination fades out gradually into the graywacke. The slate is to all appearances the same as that seen on the west side of the lake. No. 701 shows in a small way this discordance of slaty cleavage and lamination. This exposure is in the S. E. ¼ S. W. ¼ S. W. ¼ sec. 30, T. 66-5.

Several outcrops of rock varying from slate to graywacke occur on the east shore in S. W. ¼ sec. 30. The slaty cleavage and the lamination, where seen, always coincide. The strike on the little point in the W. ½ N. W. ¼ S. W. ¼ sec. 30 is N. 5° W. and the dip is 70° W. The little island just off the point in the S. W. ¼ N.

W. ¼ sec. 30 has a fine exposure. Here the bedding of the graywacke is seen to good advantage; strike N. 22° W. and dip 70° towards S. 68° W. On the point at the west entrance to the bay in E. ½ S. W. ¼ N. W. ¼ sec. 30 the strike is N. 22° W. and the dip 70° to 76° towards S. 68° W. The shores of this bay are low and show no outcrops, but on the shore about 300 feet east of the last named point is an outcrop of altered granite like No. 689. It is roughly schistose; this structure is vertical and runs north and south. Less than fifty yards east of this is a ridge of the same rock very coarse grained. A little further north (in the E. ½ N. W. ¼ sec. 30) the rock at the shore is the same as in the ridge. In places four-fifths of the rock is composed of quartz as is shown by No. 702. Apparently in this altered granite was a small, illy exposed area of brownish fissile slate. No. 703 shows this slate and No. 704 a condition of it near the ordinary altered granite. It appears as if this slate is part of the slate formation of the region enclosed in the other rock, but nothing definite could be made out concerning it.

The altered granite extends along the east shore in the N. W. ¼ sec. 30, and to the extreme northern point of the lake. Here, on the east side of the stream which flows into Saganaga lake, the rock is altered granite, but on the west side of this stream the slate and graywacke formation appears. The slates hold bands of what seem to be the altered granite, and also of graywacke and grit. It is here impossible to distinguish between these rocks, in fact it seems as if the so-called altered granite was a part of the grit and graywacke. Nos. 705, 706 and 707, from the east end of this exposure, show facies of the altered granite or of the grit and graywacke. No. 708 certainly seems to be grit; it was taken over fifty yards from the main mass of the altered granite. In one place one of these questionable bands was seen to hold fragments of slate near its edge,—No. 709. In no place did I see any of the so-called altered granite bands cutting across the strike of the slates. Nearest the main mass of altered granite the slates are brownish, as those found inclosed in the other rock (see Nos. 704 and 705) and are shown by No. 710.

The slaty formation extends along the north and west shores of of Wind lake. Northwest from the northwest corner of the lake is a high bluff composed mostly of grit and graywacke, the former apparently somewhat re-crystallized (No. 711). Here the dip is 75° to 80° towards S. 60° W. About a quarter of a mile south of this bluff the dip is 80° towards S. 70° W.

On going east from the south end of the lake to the small lake which is crossed by the south line of sec. 30, east of the quarter post, only a few outcrops were seen. These were of the same slate formation as exists on the shores of Wind lake. On the west shore of this small lake the strike is N. 20° W. and the dip 80° towards S. 70° W., but at an outcrop about an eighth of a mile west of this the strike is N. 25° E. and the dip is probably 80° towards N. 65° W., but the dip could not be accurately determined, as only a smooth glaciated surface was exposed. An outcrop on the east shore of this small lake appears to be of the same slaty formation, but it was not visited. In the E. ½ of N. W. ¼ sec. 30, the altered granite similar to No. 702 is seen.

South of Wind lake a short distance are a few outcrops of the slate formation. Here the beds are twisted somewhat, but the general strike is a little west of north. Southeast from the lake the slate outcrops extend for a quarter of a mile. The dip taken on one outcrop was vertical and the strike N. 25° W. We went east-southeast from the southeast end of Wind lake, but after passing the above mentioned outcrops of slate no other rock was seen *in situ* until coming into about the N. E. ¼ S. W. ¼ sec. 32, T. 66–5. Here the ordinary coarse grained hornblende granite occurs, but of not quite as coarse grain as that usually seen on Saganaga lake. Farther on, probably in the S. W. ¼ S. E. ¼ of the same section, granite is again seen.

On going east from Wind lake about the centre of the N. W. ¼ sec. 30, an apparent gradation is seen between the altered granite and the ordinary granite. The latter was found in the midst of the former and not separated from it by any line or sudden change. Nos. 712 to 716, together with the finer grained conditions of this rock already described, show this gradation into the ordinary granite. In its coarsest condition the altered granite is much weathered and decayed, and it is difficult to get good specimens of it. I also went east from the lake a short distance on the north line of sec. 30, and then northeast to the bay of Saganaga lake in the S. W. ¼ sec. 19, T. 66–5, and saw essentially the same gradations. In places the altered granite has irregular areas in which the large quartz grains are lacking and the rock is almost entirely composed of a fine greenish material, as seen in specimens Nos. 688 and 689. In a few places the large quartz grains were arranged along definite, distinct lines or "beds," and this arrangement faded off into the main mass of the rock where no arrangement of the grains could be seen. These "beds" ran from 10° to 30° W. of N. and seemed to stand vertical.

347 and 348. Red syenite. West line of sec. 5, T. 62–10, north of the Kawishiwi river. P. 41.

349. Hornblende vein rock. Same locality. P. 41.

350. Dark red syenite. Near the west line of sec. 5, T. 62–10, north shore of the Kawishiwi river. P. 42.

351. Dark coarse syenite. Same locality. P. 42.

352 to 354. Coarse dark diorite. S. W. ¼ N. W. ¼ sec. 5, T. 62–10, north shore of the Kawishiwi river. P. 42.

355. Syenite. S. E. ¼ N. E. ¼ sec. 5, T. 62–10, Kawishiwi river. P. 42.

356. Red hornblende granite. N. W. ¼ S. W. ¼ sec. 9, T. 62–10, south shore of the Kawishiwi river. P. 42.

357. Gabbro. S. W. ¼ S. W. ¼ sec. 9, T. 62–10. P. 42.

358. Fine grained biotite granite. Same locality. P. 42.

359. Biotite syenite. Same locality. P. 42.

360. Red aplite. Same locality. P. 42.

361. Fine micaceous syenite. S. W. ¼ sec. 9, T. 62–10, east shore of the Kawishiwi river. P. 42.

362. Fine gray syenite. Same locality. P. 42.

363 and 364. Intermediate between gabbro and syenite. Same locality. P. 42.

365. Purple porphyrite (?). Same locality. P. 43.

366. Dark syenite. Sec. 34 (?), T. 63–10, west shore of the Kawishiwi river. P. 43.

367. Syenite. Same locality. P. 43.

368. Coarse syenite. S. W. ¼ sec. 34, T. 63–10, west shore of the Kawishiwi river. P. 43.

369. Coarse diorite. Just north of the centre of sec. 26, T. 63–10, south shore of the Kawishiwi river. Pp. 44–45.

370. Trap dyke rock. Same locality. P. 45.

371. Fine red granite. Same locality. P. 45.

372. Fine gray granite. Just west of the last. P. 45.

373. Diorite. Same locality. P. 45.

374. Diorite and granite in contact. Same locality. P. 45.

375. Coarse diorite. S. W. ¼ sec. 26, south shore of the Kawishiwi river. P. 45.

376. Diorite, fine grained. N. W. ¼ S. W. ¼ sec. 26, T. 63–10, south shore of the Kawishiwi river. P. 45.

377. Coarse red syenite. S. W. ¼ S. W. ¼ sec. 26, T. 63–10, south shore of the Kawishiwi river. P. 45.

378. Gneiss inclusion in the syenite. Same locality. P. 45.

379. Greenstone. West line of sec. 22, T. 63–10, north of the Kawishiwi river. P. 45.

380. Greenstone. Same locality. P. 45.

381. Quartz porphyry. Same locality. P. 45.

382. Greenstone. West line of sec. 22, T. 63–10, ¾ mile north of the Kawishiwi river. P. 46.

383. Fine graywacke. N. E. ¼ N. E. ¼ sec. 28, T. 63–10, north shore of the Kawishiwi river. P. 46.

384. Coarser graywacke. Same locality. P. 46.

385. Coarse graywacke. N. E. ¼ N. E. ¼ sec. 28, T. 63–10, north shore of the Kawishiwi river. P. 46.

386. Finer graywacke; Same locality. P. 46.

387. Gneissic syenite. N. E. ¼ N. E. ¼ sec. 28, T. 63–10, portage along north side of the Kawishiwi river. P. 46.

388. Fissile greenstone. N. W. ¼ N. E. ½ sec. 28, T. 63–10, portage along north side of the Kawishiwi river. P. 46.

389 to 394. Specimens illustrating passage from greenstone to syenite. Same locality. P. 47.

395. Finely jointed greenstone. Same locality. P. 47.

395A. Sericitic graywacke. N. E. ¼ N. W. ¼ sec. 28, T. 63–10, portage along the north side of the Kawishiwi river. P. 47.

396. Contact of graywacke and syenite. Same locality. P. 47.

397 to 400. Facies of the syenite near the contact. Same locality. P. 47.

401. Greenstone. Same locality. P. 47.

402. Quartz porphyry from edge of dyke. N. ½ N. W. ¼ sec. 28, T. 63–10, north shore of the Kawishiwi river. P. 48.

403. The same from center of dyke, Same locality. P. 48.

404. Gray gniess. S. E. ¼ N. W. ¼ sec. 28, T. 63–10, south of the Kawishiwi river. P. 48.

405. Sericitic schist. Same locality. P. 49.

406 to 408. Gray gneiss. Same locality. P. 49.

409. Diorite in the gneiss. Same locality. P. 49.

410. Red syenite. N. E. ¼ N. E. ¼ sec. 29, T. 63–10, north shore of the Kawishiwi river. P. 49.

411. Quartzporphyry. N. ½ N. E. ¼ sec, 29, T. 63–10, north shore of the Kawishiwi river. P. 49.

412. Greenstone. West line of sec. 21, T. 63–10, one-eighth mile north of the S. W. corner of this section. P. 56.

413. Gray granite porphyry. N. W. ¼ S. E. ¼ sec. 20, T. 63–10, west shore of lake. P. 56.

414. Quartzporphyry (?). N. W. ¼ N. E. ¼ sec. 21, T. 63–10, north shore of lake. P. 56.

415. Greenstone near dyke walls. N. ½ N. E. ¼ sec. 21, T. 63–10, south shore of lake. P. 57.

416. Quartz porphyry at edge of dyke. Same locality. P. 57.

417. The same from center of dyke. Same locality. P. 57.

418. Greenstone. South line of sec. 16, T. 63–10, north shore of lake. P. 57.

419. Magnetite slate. East line of sec. 16, T. 63–10, a short distance north of the quarter post. P. 58.

420 to 422. Sericitic gneiss near syenite contact. Near the west line of sec. 28, T 63–10, one-third mile south of the Kawishiwi river. P. 50.

423. Gneiss and syenite in contact. Same locality. P. 50.

424. Gneissic syenite near the contact with the gneiss. Same locality. P. 50.

425. Red syenite. Same locality. P. 50.

426. Sericitic schist. Near the west line of sec. 29, T. 63–10, south of the Kawishiwi river. P. 50.

427. Mica-schist. Same locality. P. 50.

428. Syenite porphyry (?). N. ½ N. W. ¼ sec. 29, T. 63–10, north of the Kawishiwi river. P. 51.

429 to 431. Gray gneiss. Small island in the bay in the N. W. ¼ N. W. ¼ sec. 27, T. 63–10, Kawishiwi river. P. 51.

432. Reddish syenite. Same locality. P. 51.

433. Schist inclusion in syenite. Same locality. P. 51.

434. Mica-schist from inclusion in syenite. East shore of the same bay. P. 51.

435 Mica-schist and syenite in contact. Same locality. P. 51.

436. Schistose syenite. S. E. corner of bay in N. E. ¼ N. W. ¼ sec 27, T. 63–10, Kawishiwi river. P. 51.

437. Gneissic syenite (?). Same locality. P. 51.

438. Gneiss. Same locality. P. 51.

439. Granite vein rock. Same locality. P. 52.

440. Schistose syenite. N. ½ sec. 27, T. 63–10, north shore of the Kawishiwi river. P. 52.

441. Chloritic syenite. Same locality. P. 52.

442. Dark gneiss. N. E. ¼ N. E. ¼ sec. 27, T. 63–10, north shore of the Kawishiwi river. P. 53.

443 and 444. Sericitic gneiss. N. W. ¼ N. W. ¼ N. W. ¼ sec. 26, T. 63-10, north shore of the Kawishiwi river. P. 53.

445. Gray hornblende gneiss. Same locality. P. 53.

446. Gneiss and green inclusion. Same locality. P. 53.

447. Mica-schist. N. W. ¼ N. W. ¼ sec. 26, T. 63–10, north shore of the Kawishiwi river. P. 53.

448. Greenstone inclusion in syenite. N. W. ¼ N. W. ¼ sec. 26, T. 63–10, north of the Kawishiwi river. P. 54.

449. Schistose greenstone. Same locality. P. 54.

450. Diorite. East shore of the bay which is crossed by the south line of sec. 23, T. 63–10, Kawishiwi river. P. 54.

451. Diorite and syenite in contact. Same locality. P. 54.

452. Pegmatite. Same locality. P. 54.

453 to 455. Siliceous schist. N. E. ¼ S. W. ¼ sec. 24, T. 63–10, portage from the Kawishiwi river to Triangle lake. P. 58.

456. Greenstone. Same locality. P. 58.

457. Green slate. S. E. ¼ N. W. ¼ sec. 24, T. 63–10, same portage. P. 58.

458. Altered quartz porphyry. N. E. ¼ N. W. ¼ sec. 13, T. 63–10, south side of small island in Northwest lake. P. 58.

459. Mottled greenstone. N. E. ¼ N. E. ¼ sec. 13, T. 63–10, north shore of Northwest lake. P. 58.

460. Gabbro and biotite syenite in contact. N. W. ¼ sec. 25, T. 63–10, south shore of the Kawishiwi river. P. 55.

461. Gray syenite. Same locality. P. 55.

462. Red syenite. Same locality. P. 55.

463. Gray syenite. Sec. 26, T. 63–10, Kawishiwi river. P. 55.

464. to 466. Rock intermediated between syenite and gabbro. N. ½ S. W. ¼ sec. 19, T. 62–9, island in the Kawishiwi river. P. 55.

467. Syenite. Same locality. P. 55.

468. Gabbro. N. ½ S. W. ¼ sec. 19, T. 63–9, south shore of the Kawishiwi river. P. 55.

469. Syenite. Same locality as No. 467. P. 55.

470. Rock intermediade between gabbro and syenite. Near the center of sec. 19, T. 63–9, point on north side of the Kawishiwi river. P. 55.

471 and 472. Greenstone. S. E. ¼ N. W. ¼ sec. 19, T. 63–9, north shore of the Kawishiwi river. P. 56.

473. Diorite. West line of sec. 20, T. 63–9, north of the Kawishiwi river. P. 56.

### SNOWBANK LAKE AREA.

474. Coarse syenite. Sec. 11, T. 63–9, portage from the Kawishiwi river to Snowbank lake. P. 60.

475. Fine red syenite. Same locality. P. 60.

476. Syenite. Same locality. P. 60.

477. Diorite. Same locality. P. 60.

478. Fine syenite. Same locality. P. 60.

479. Fine diorite. Same locality. P. 60.

480 and 481. Gray porphyritic syenite. Same locality. P. 60.

482. Fine syenite. N. ½ N. E. ¼ sec. 11, T. 63–9, west shore of Snowbank lake. P. 60.

483. Dark red syenite. S. ½ S. E. ¼ sec. 2, T. 63–9, west shore of Snowbank lake. P. 60.

484. Gray Syenite. Same locality. P. 60.

485. Syenite. N. W. ¼ S. E. ¼ sec. 2, T. 63–9, island in Snowbank lake. P. 60.

486. Reddish syenite vein rock. Same locality. P. 60.

487. Diorite. West line of sec. 36, T. 64–9, south shore of Snowbank lake. P. 61.

488. Coarse syenite. S. E. ¼ sec. 35, T. 64–9, south shore of Snowbank lake. P. 61.

489. Fine syenite. S. E. ¼ N. W. ¼ sec. 35, T. 64–9, south shore of Snowbank lake. P. 61.

489A. Fine diabase. S. E. ¼ S. E. ¼ sec. 27, T. 64–9, west shore of Snowbank lake. P. 61.

490. Syenite porphyry. Same locality. P. 61.

491. Fine reddish hornblende granite. North line of sec. 35, T. 64–9, west shore of Snowbank lake. P. 62.

492. Mica-schist. N. E. ¼ N. W. ¼ sec. 35, T. 64–9, west shore of Snowbank lake. P. 62.

493. Gneiss. Same locality. P. 62.

494 and 495. Gneiss near granite contact. Same locality. P. 62.

496. Gneiss and granite in contact. Same locality. P. 62.

497. Syenite porphyry. S. E. ¼ S. W. ¼ sec. 26, T. 64–9, west shore of Snowbank lake. P. 63.

498. Hornblende granite. S. E. ¼ S. W. ¼ sec. 26, T. 64–9, island in Snowbank lake. P. 63.

499. Gray biotite gneiss. S. E. ¼ S. W. ¼ sec. 26, T. 64–9, west shore of Snowbank lake. P. 64.

500. Syenite porphyry from centre of dyke. Same locality. P. 64.

501. The same from edge of dyke. Same locality. P. 64.

502. Hard green schist. N. W. ¼ S. W. ¼ sec. 26, T. 64–9, west shore of Snowbank lake. P. 65.

502A. Gneiss from pebble in the schist. Same locality. P. 65.

503. Fine hornblende granite. Same locality. P. 65.

504. Porphyrite. N. W. ¼ S. W. ¼ sec. 26, T. 64–9, west shore of Snowbank lake. P. 65.

505. Schistose condition of the same. Same locality. P. 65.

506. Fine syenite dyke rock. Same locality. P. 65.

507. Mottled diorite. S. W. ¼ N. E. ¼ sec. 26, T. 64–9, west shore of Snowbank lake. P. 65.

508. Greenstone. Same locality. P. 65.

509. Red syenite. Same locality. P. 65.

510. Greenstone. Same locality. P. 65.

511. Mica-schist. N. E. ¼ sec. 26, T. 64–9, west shore of Snowbank lake. P. 65.

512. Green schist. Same locality. P. 65.

513. Hornblende granite. Same locality. P. 66.

514. Graywacke. Near the north line of sec. 26, T. 64–9, west shore of Snowbank lake. P. 66.

515. Siliceous schist. S. E. ¼ S. E. ¼ sec. 23, T. 64–9, west shore of Snowbank lake. P. 66.

516. Green schist. Sec. 24, T. 64–9, north shore of Snowbank lake. P. 66.

517. Siliceous schist. Same locality. P. 66.

518. Hornblende granite. East line of sec. 24, T. 64–9, north shore of Snowbank lake. P. 66.

519. Contact of schist and granite. Same locality. P. 66.

520. Siliceous mica-schist near granite contact. Same locality. P. 66.

521. Fine dark syenite. Same locality. P. 66.

522. Syenite. N. E. ¼ S. W. ¼ sec. 19, T. 64–8, island in Snowbank lake. P. 66.

523. Light gray syenite. N. W. ¼ S. W. ¼ sec. 29, T. 64–8, east shore of Snowbank lake. P. 66.

524. Coarse biotitic syenite. Near south line of sec 30, T. 64–8, east shore of the largest island in Snowbank lake. P. 67.

525.* Biotite gneiss. N. W. ¼ N. E. ¼ sec. 31, T. 64–8, south end of island in Snowbank lake. P. 67.

526. Reddish syenite. N. E. ¼ sec. 1, T. 63–9, portage from Snowbank to Round lake. P. 67.

527. Mica-schist cut by syenite veins. N. E. ¼ S. E. ¼ sec. 1, T. 63-9, north shore of Round lake. P. 67.

528 and 529. Gneiss. N. E. ¼ S. E ¼. sec. 1, T. 63–9, west shore of Round lake. P. 67.

530. Fine red syenite. Same locality. P. 67.

531 and 532. Gneiss. Same locality. P. 67.

533. Brown syenite (?). N. E. ¼ N. W. ¼ sec. 7, T. 63–8, south shore of Round lake. P. 67.

534. Fine red syenite. E. ½ sec. 6, T. 63–8, east shore of Round lake. P. 68.

535. Syenite and fine gabbro (?) in contact. N. W. ¼ N. E. ¼ sec. 7, T. 63–8, south shore of Round lake. P. 68.

536. Fine gabbro (?). Same locality. P. 68.

537. Gabbro. Same locality. P. 68.

538. Gray syenite (?). S. ½ S. W. ¼ sec. 32, T. 64–8, portage between Disappointment and Snowbank lakes. P. 68. [Note: No. 539, on p. 68, should be No. 538.]

539. Fine red syenite. Same locality. P. 69.

### KEKEQUABIC LAKE AREA.

540. Soft green biotite schist. N. E. ¼ N. W. ¼ sec. 11, T. 64–7, portage south of Kekequabic lake. P. 69.

541. Fine gabbro (?). W. ½ sec. 11, T. 64–7, west end of River lake. P. 69.

542. Finer facies of the same. N. E. ¼ S. E. ¼ sec. 11, T. 64–7, portage from River to Shoofly lake. P. 69.

543. Streaks of biotite in the same. S. E. ¼ N. W. ¼ sec. 11, T. 64–7, River lake. P. 69.

544. Greenstone from the fine gabbro (?). S. E. ¼ N. W. ¼ sec. 11, T. 64–7, River lake. P. 69.

545. Fragments of syenite in the fine gabbro (?). Same locality. P. 69.

546. Gray syenite. N. E. ¼ S. W. ¼ sec. 11, T. 64–7, south shore of River lake. P. 69.

547. Fine biotitic gabbro (?). S. E. ¼ N. W. ¼ sec. 11, T. 64–7, east shore of River lake. P. 70.

548. Fine gray gabbro (?). Same locality. P. 70.

549. Pyroxene granite. S. E. ¼ S. W. ¼ sec. 2, T. 64–7, south shore of Kekequabic lake. P. 70.

550. Diorite (?). S. E. ¼ S. W. ¼ sec. 3, T. 64–7, south shore of Kekequabic lake. P. 71.

551. Porphyritic pyroxene granite. S. W. ¼ S. W. ¼ sec. 3, T. 64–7, south shore of Kekequabic lake. P. 71.

552. Hardened black slate. Same locality. P. 71.

553. Pyroxene granite. S. W. ¼ N. W. ¼ sec. 3, T. 64–7, west shore of Kekequabic lake. P. 71.

554. Contact of diorite and granite. Same locality. P. 71.

555. Diorite. Same locality. P. 71.

556. Pyroxene granite. Same locality. P. 72.

557. Finer facies of the same. Same locality. P. 72.

558. Granite porphyry (?). S. W. ¼ N. W. ¼ sec. 3, T. 64–7, small island in Kekequabic lake. P. 72.

559. Black argillyte. Same locality. P. 72.

560. Granite porphyry. Same locality. P. 72.

561. Coarse diorite. S. W. ¼ N. W. ¼ sec. 3, T. 64–7, small island in Kekequabic lake. P. 73.

562. Finer diorite. Same locality. P. 73.

563. Spotted black argillyte. S. W. ¼ N. W. ¼ sec. 3, T. 64–7, west shore of Kekequabic lake. P. 73.

564. Green schist. S. E. ¼ N. W. ¼ sec. 4, T. 64–7, west shore of Kekequabic lake. P. 73.

565. Fine pyroxene granite. S. E. ¼ N. W. ¼ sec. 3, T. 64–7, small island in Kekequabic lake. P. 73.

566. Coarser pyroxene granite. Another island in the same $\frac{1}{16}$ section. P. 73.

567. Fine dark facies of the granite (?). S. W. ¼ N. E. ¼ sec. 3, T. 64–7, north shore of largest island in Kekequabic lake. P. 73.

568. Black slate in the granite. Same locality. P. 73.

569. Chloritic conglomerate. N. E. ¼ N. W. ¼ sec. 11, T. 64–7, east shore of Kekequabic lake. P. 73.

570. Green schist. Same locality. P. 74.

571. Fine pyroxene granite. S. W. ¼ S. E. ¼ sec. 2, T. 64–7, just east of Kekequabic lake. P. 74.

572. Inclusion in the granite. Same locality. P. 74.

573. Porphyritic pyroxene granite. N. W. ¼ N. W. ¼ sec. 2, T. 64–7, small island in Kekequabic lake. P. 74.

574. Mica diorite (?). Same locality. P. 74.

575. Contact of the last two. Same locality. P. 74.

576. Fine pyroxene granite. S. W. ¼ S. E. ¼ sec. 35, T. 65–7, south shore of Kekequabic lake. P. 74.

577. Pyroxene granite porphyry. S. E. ¼ S. E. ¼ sec. 35, T. 65–7, south shore of Kekequabic lake. P. 74.

578. Purple granite porphyry. Same locality. P. 74.

579. Fine pyroxene granite. S. E. ¼ S. W. ¼ sec. 36, T. 65–7, just south of Kekequabic lake. P. 75.

580. Granite porphyry at contact with conglomerate. S. ½ N. E. ¼ sec. 36, T. 65–7, south shore of Kekequabic lake. P. 75.

581. Conglomerate at contact with granite porphyry. Same locality. P. 75.

582. Granite porphyry. Same locality. P. 75.

583. Granite porphyry carrying biotite. N. ½ S. W. ¼ sec. 36, T. 65–7, Stacy island, Kekequabic lake. P. 76.

584. Fine diabase. S. E. ¼ N. E. ¼ sec. 36, T. 65–7, northeast shore of small lake. P. 81.

585. Granite porphyry. Same locality. P. 81.

586. Granite porphyry. Same locality. P. 81.

587. The same from contact with diabase. Same locality. P. 81.

588. Granite porphyry. S. E. ¼ N. E. ¼ sec. 36, T. 65–7, north shore of small lake. P. 81.

589. Fine pyroxene granite. N. W. ¼ S. E. ¼ sec. 36, T. 65–7, west shore of small lake. P. 81.

590. Fine pyroxene granite. A short distance south of the last. P. 81.

591. Gray granite porphyry. N. E. ¼ S. E. ¼ sec. 36, T. 65–7, south shore of small lake. P. 82.

592. Inclusion in granite porphyry. N. E. ¼ S. E. ¼ sec. 36, T. 65–7, east shore of small lake. P. 82.

593. Metamorphosed conglomerate. S. W. ¼ N. W. ¼ sec. 31, T. 65–6, south shore of Kekequabic lake. P. 76.

594. Metamorposed conglomerate. N. E. ¼ S. W. ¼ sec. 31, T. 65–6, south shore of Kekequabic lake. P. 76.

594A. Pebbles from the same. Same locality. P. 76.

595. Metamorphosed conglomerate. S. E. ¼ N. E. ¼ sec. 31, T. 65–6, south shore of Kekequabic lake. P. 76.

596. Granite porphyry. E. ½ S. E. ¼ N. E. ¼ sec. 31, T. 65-6, south shore of Kekequabic lake. P. 77.

597. Granite porphyry at contact with diabase. Same locality. P. 77.

598. Fine diabase at contact with granite porphyry. Same locality. P. 77.

599. Fine diabase. Same locality. P. 77.

600. Coarser condition of the same. Same locality. P. 77.

601 to 615. Specimens showing gradations from a gray slate (?) to the pyroxene granite. S. W. ¼ N. W ¼ sec. 3, T. 64–7, west shore of Kekequabic lake. P. 72.

616. Granite porphyry. W. ½ N. E. ¼ N. W. ¼ sec. 31, T. 65–6, north shore of Kekequabic lake. P. 77.

617. Granite porphyry near contact with greenstone. Same locality. P. 77.

618. Greenstone near contact with granite porphyry. Same locality. P. 77.

619. Greenstone. Same locality. P. 77.

620. Inclusion in granite porphyry. Same locality. P. 77.

621. Granite porphyry. S. W. ¼ S. W. ¼ sec. 29, T. 65–6, north shore of Kekequabic lake. P. 77.

621A, 621B and 621C. Inclusions in granite porphyry. N. W. ¼ N. W. ¼ sec. 32, T. 65–6, north shore of Kekequabic lake. P. 77.

622. Purple slate. N. E. ¼ S. W. ¼ sec. 36, T. 65–7, south shore of Kekequabic lake. P. 78.

623. Pyroxene granite. Same locality. P. 78.

624. Pyroxene granite at contact with purple slate. Same locality. P. 78.

625. Purple slate at contact with granite. Same locality. P. 78.

626. Hardened slate (?). Same locality. P. 78.

627. Gray slate. Same locality. P. 78.

628. Granite porphyry at contact with greenstone. N. E. ¼ N. E. ¼ sec 36, T. 65–7, north shore of Kekequabic lake. P. 78.

629. Granite porphyry. Same locality. P. 78.

630. Metamorphosed conglomerate. N. W. ¼ S. E. ¼ sec. 31, T. 65–6, south of Kekequabic lake. P. 79.

631. Black slate. N. W. ¼ S. E. ¼ sec. 31, T. 65-6, south of Kekequabic lake. P. 79.

632. Grit. S. W. ¼ S. E. ¼ sec. 31, T. 65–6. P. 79.

633. Grit and slate interbanded. Same locality. P. 79.

634. Grit. N. W. ¼ N. E. ¼ sec. 6, T. 64–6. P. 79.

635. Grit. S. W. ¼ S. E. ¼ sec. 6, T. 64–6. P. 79.

636. Granite porphyry (?). S. W. ¼ N. E. ¼ sec. 7, T. 64–6. P. 80.

637. Green conglomerate. N. E. ¼ S. W. ¼ sec. 7, T. 64–6, north of small lake. P. 80.

638. Crystalline conglomerate. S. E ¼ S. W. ¼ sec. 7, T. 64–6, just north of small lake. P. 80.

639. Gabbro. S. ½ S. E. ¼ sec. 7, T. 64–6, east shore of small lake. P. 80.

640. Porphyritic (?) conglomerate. S. E. ¼ S. E. ¼ sec. 29, T. 65–6, east end of portage. P. 82.

641. Green conglomerate. Same locality. P. 82.

642. Metamorphosed grit (?). S. W. ¼ S. W. ¼ sec. 26, T. 65-6, east shore of small lake. P. 82.

643. Fine diabase. Same locality. P. 82.

644. Metamorphosed grit (?) at contact with diabase. Same locality. P. 82.

## SAGANAGA LAKE AREA.

645. Coarse gray granite. N. E. ¼ N. W. ¼ sec. 17, T. 65–5, West Sea Gull lake. P. 83.

646. Decayed granite. Same locality. P. 83.

647. Coarse granite. N. E. ¼ N. E. ¼ sec. 17, T. 65–5. P. 83.

648. Green slate. N. W. ¼ N. E. ¼ sec. 17, T. 65–5, south shore of West Sea Gull lake. P. 83.

649. Coarse granite vein rock. Same locality. P. 83.

650. Fine reddish granite vein rock. Same locality. P. 83.

651. Greenstone. N. E. ¼ N. W. ¼ sec. 17, T. 65-5, south shore of West Sea Gull lake. P. 83.

652. Diabase. Same locality. P. 83.

653. Fine graywacke. S. W. ¼ S. W. ¼ sec. 8, T. 65–5, west shore of West Sea Gull lake. P. 84.

654. Ogishke Muncie conglomerate. N. W. ¼ S. W. ¼ sec. 8, T. 65–5, west shore of West Sea Gull lake. P. 84.

655. Granite. N. E. ¼ S. E. ¼ sec. 7, T. 65–5, just west of West Sea Gull lake. P. 84.

656. Ogishke Muncie conglomerate at contact with granite. N. W. ¼ N. E. ¼ S. E. ¼ sec. 8, T. 65–5. P. 84.

657. Granite at contact with conglomerate. Same locality. P. 84.

657A. Granite. Same locality. P. 84.

658. Matrix of conglomerate. Same locality. P. 84.

659. Fine green matrix of conglomerate. Same locality. P. 85.

660. Purple porphyrite (?) at contact with granite. N. ½ S. W. ¼ N. W. ¼ sec. 8, T. 65–5, west shore of West Sea Gull lake. P. 85.

661. Purple porphyrite (?). Same locality. P. 85.

662. Diabase from dyke. N. W. ¼ S. W. ¼ sec. 5, T. 65–5, west shore of West Sea Gull lake. P. 85.

663. Green slate. E. ½ N. E. ¼ S. E. ¼ sec. 6, T. 65–5. P. 85.

664. Grit. Same locality. P. 85.

665. Granite. W. ½ N. W. ¼ N. W. ¼ sec. 8, T. 65–5, west shore of small lake. P. 86.

666. Decayed granite. W. ½ N. W. ¼ N. W. ¼ sec. 8, T. 65–5, just west of small lake. P. 86.

667. Decayed granite. Same locality. P. 87.

668. Decayed granite (?). Same locality. P. 87.

669. Hardened mica-schist. E. ½ S. E. ¼ N. E. ¼ sec. 17, T. 65–5, west shore of small lake. P. 87.

670. Green siliceous schist. S. ½ S. W. ¼ N. W. ¼ sec. 16, T. 65–5, south shore of small lake. P. 87.

671. Decayed granite. West line of sec. 15, T. 65–5, south shore of Sea Gull lake. P. 88.

672. Fine gray granite. West line of sec. 15, T. 65–5, just north of the southwest corner of this section. P. 88.

673. Mica-schist. West line of sec. 22, T. 65–5, just south of the northwest corner of this section. P. 88.

674. Quartz porphyry. Same locality. P. 88.

675. Typical hornblende granite. S. W. ¼ S. E. ¼ sec. 8, 65–5, east shore of small island in West Sea Gull lake. P. 86.

676. Gray fluorite granite. S. E. ¼ N. W. ¼ sec. 14, T. 66–5, island in Saganaga lake. P. 89.

677 and 678. Red fluorite granite. Same locality. P. 89.

679 and 680. Altered granite. N. E. ¼ N. W. ¼ sec. 14, T. 66-5, south shore of island in Saganaga lake. P. 89.

681. Red aplite at contact with granite. S. E. ¼ S. E. ¼ sec. 8, T. 66-5, island in Saganaga lake. P. 89.

682. Red aplite. Same locality. P. 89.

683. Coarse hornblende granite. S. ½ S. E. ¼ sec. 18, T. 66-5, island in Saganaga lake. P. 90.

684. Altered granite. S. E. ¼ N. E. ¼ S. E. ¼ sec. 18, T. 66-5, south shore of Saganaga lake. P. 90.

685. Altered granite. S. W. ¼ S. E. ¼ sec. 18, T. 66-5, south shore of Saganaga lake. P. 90.

686. Typical coarse hornblende granite. S. W. ¼ N. E. ¼ sec. 22, T. 66-5, west shore Saganaga lake. P. 88.

687. Altered granite. West line of sec. 19, T. 66-5, south shore of Saganaga lake. P. 90.

688. Green altered granite. Canadian shore, just north of the last. P. 90.

689. Weathered condition of the same. Same locality. P. 90.

690. Altered granite. E. ½ N. E. ¼ S. E. ¼ sec. 24, T. 66-6, east shore of bay of Saganaga lake. P. 90.

691. Gray slate. Same locality. P. 90.

692 to 694. Altered granite. Same locality. Pp. 90, 91.

695. Graywacke. Same locality. P. 91.

696. Drab fissile slate. Same locality. P. 91.

697. Green slate. S. E. ¼ N. E. ¼ sec. 25, T. 66-6, west shore of Wind lake. P. 93.

698. Graywacke. Same locality. P. 93.

699. Grit. Same locality. P. 93.

700. Graywacke. N. E. ¼ S. E. ¼ sec. 25, T. 66-6, west shore of Wind lake. P. 93.

701. Slate showing discordance of lamination and slaty cleavage. S. E. ¼ S. W. ¼ S. W. ¼ sec. 30, T. 66-5, just east of Wind lake. P. 93.

702. Altered granite. E. ½ N. W. ¼ sec. 30, T. 66-5, east shore of Wind lake. P. 94.

703. Brown fissile slate. Same locality. P. 94.

704. Coarse condition of the same. Same locality. P. 94.

705 to 707. Altered granite (?). S. W. ¼ S. W. ¼ S. W. ¼ sec. 19, T. 65-5, north shore of Wind lake. P. 94.

708. Grit. Same locality. P. 94.

709. Grit (?). Same locality. P. 94.

710. Brown fissile slate. Same locality. P. 94.

711. Grit. S. E. ¼ S. W. ¼ S. W. ¼ sec. 24, T. 66-6, just northwest of Wind lake. P. 94.

712 to 716. Specimens showing gradation from the altered granite to the ordinary granite. N. W. ¼ sec, 30, T. 66-5, east of Wind lake. P. 95.

717 to 725. Specimens showing gradation from the altered granite to the ordinary fresh granite. N. W. ¼ S. W. ¼ sec. 19, T. 66-5, south shore of Saganaga lake. P. 92.

726. Greenstone inclusion in granite. Same locality. P. 92.

727. Altered granite (?). E. ½ S. E. ¼ sec. 24, T. 66-6, east shore of bay of Saganaga lake. P. 91.

728. Graywacke. Same locality. P. 91.

729 to 732. Grit. Same locality. Pp. 91, 92.

733. Altered granite. S. E. ¼ N. E. ¼ sec. 24, T. 66-6, portage from Saganaga lake to Oak lake. P. 92.

734. Altered granite (?). Sec. 24, T. 66-6, south shore of Oak lake. P. 92.

# IV.

# THE MESABI IRON RANGE.

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HORACE V. WINCHELL, F. G. S. A.

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# THE MESABI IRON RANGE.

### DISCOVERY OF THE ORE.

On the sixteenth day of November, 1890, workmen under the direction of Capt. J. A. Nichols, of Duluth, Minnesota, encountered soft hematite in a test-pit on the northwest quarter of section three, township fifty-eight, range eighteen, west of the fourth principal meridian. This mine, now called the Mountain Iron, was the first body of soft ore discovered on the Mesabi iron range. Hard ore, chiefly magnetic, had been known for many years on the Mesabi, and explorations made by Mr. E. W. Griffin, of Minneapolis, near the falls of Prairie river in townships 56–24 and 56–25, had revealed some hard hematite interbedded with quartzyte and low grade soft ore. This, however, was the first merchantable deposit of hematite found on the new range. Capt. Nichols had been doing more or less exploring work along the range for some two years prior to this discovery. The Merritt brothers, of Duluth and Oneota, were not to be discouraged by the reports of explorers and miners added to those of experts and geologists who had condemned the range ever since 1875. To these Duluth pioneers the Mesabi was an attractive and promising district and their faith in it was never shaken, even though their ready cash was spent vainly and two years' searching remained unrewarded. To them belongs the credit for persisting in the hunt for ore and the final discovery of it, and to them rightfully and properly have large rewards already been granted.

### WHAT EARLY EXPLORERS HAD SAID.

The Mesabi range attracted attention to its iron belt as early as 1875, and several iron experts of good repute were sent to examine the various outcrops of ore known at that time. The journey was an arduous one into a dense wilderness, and there is no wonder they did no test-pitting or drilling. They were sent to examine outcrops which they properly enough condemned, for the only iron to be seen was in thin strata of magnetite banded with jaspery quartzyte, under which, in some places, could be seen the rocks of the Archean.

Professor A. H. Chester, of Hamilton, N. Y., was one who visited the Mesabi in 1875. His account of the ores and rocks there may be found in the eleventh annual report of the Minnesota geological survey, pages 154 to 167.

Capt. A. P. Wood and others were sent to the very property now owned by the Mountain Iron Company, about eight years ago, and seeing nothing but the lean outcrops mentioned above reported adversely on it.

In fact the opinion of these early explorers was unanimously unfavorable to the range. Some of them found the titaniferous ore of the gabbro and drew the hasty conclusion that all the ores on the range would be worthless on account of titanium. The impression gained ground after the mines on the Vermilion range were opened that there was no ore worth mining on the Mesabi, because it consisted of nearly horizontal strata, or, in miner's parlance, was a "blanket formation." The ore deposits in the ranges on the south shore of lake Superior are all inclined at high angles, and a flat deposit of ore of any considerable purity and thickness was unknown in this country. In spite of all this unfavorable opinion on the part of those who should be competent to judge, and against the advice of their friends, the Merritts continued to look for outcrops and dig holes in the ground, and never ceased to dream of hidden stores of iron treasure.

It should here be stated that the opinion of the State Geologist and his assistants was again and again expressed in conversation and put on record in various reports to the effect that the Mesabi was likely to yield large quantities of good ore. It was shown by diagrams that the formation, although a flat one, did contain good ore, and it was indicated where the ore would occur in relation to the other rocks of the range. The order of stratification was studied and explained two or three years before any ore was discovered, and finally we even went so far as to hazard the prediction that the Mesabi range was likely to produce more ore even than the Penokee-Gogebic.*

This and many other statements of similar import put the geological survey on record as favoring the Mesabi, against the opinion of nearly all the actual mine operators and scientists who had examined it.

If the geology of the range as it was described in the annual reports of 1887 and 1888 were better understood by the explorers on the range at the present time there would be fewer test-pits sunk in greenstone, granite and quartzyte and more dollars in the pockets of those who are still vainly searching for ore.

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*Bulletin No. 6, p. 160.

It is not the province of the state geological survey to find iron mines; that is the business of the explorer. A geologist's duty is by study and observation to indicate the proper conditions for ore deposits and the geographic limits of the formations in which those conditions may exist. The intelligent and unbigoted explorer will assimilate these ideas and apply them in discovering the stores of hidden wealth. The work of sinking test-pits is work of exploration, not geological work. As soon as a geologist begins to apply his ideas and dig holes he becomes an explorer, and in that work is a geologist no longer. We confess that we take considerable pride in the fact that our predictions in regard to the Mesabi are now in such rapid process of fulfillment.

There are several prominent citizens of Duluth and others who took an early interest in the Mesabi and assisted largely in its rapid development. It is due to their energy and confidence in the new range that there has been begun the exploitation of the greatest iron range in the world, in the most wonderfully rapid and unprecedented fashion. Among these pioneers of development should be mentioned judge J. T. Hale and his partner, E. C. Gridley; A. E. Humphrey, Geo. E. Milligan and others in the firm of A. E. Humphrey & Co., who undoubtedly were engaged in the largest transactions consummated on the range during the first year of its discovery, and whose exertions have resulted in the most extensive discoveries, perhaps several years in advance of the natural process of development; Frank Hibbing, A. J. Trimble, James Billings, John, William and Duncan McKinley, D. T. Adams, J. T. James, Hon. O. D. Kinney, Joseph Sellwood, J. G. Cohoe, P. L. Kimberley, J. T. Jones, J. A. Crowell, James Sheridan, and many others whose names are not now recalled. Judge Hale, especially, through the observations of John McCaskill and B. T. Hale, began exploration work in a systematic and thorough manner. McCaskill's keen eye discovered ore clinging to the roots of an upturned tree on the Cincinnati property, and by tracing out from there the approximate course of the green schist ridges enabled judge Hale and his coöperators to early select and secure possession of some of the best lands in 58–16. The value of clear and accurate observation and shrewd deduction from the facts observed, as to the best location for iron ore deposits and the situations in which they were most likely to occur, was soon made apparent on this range. Those who selected lands by chance, even though they purchased whole sections, did not get as much iron ore as those who applied what knowledge was to be obtained in the selection of promising pieces. The difficulties of becoming acquainted with such a wilderness and the new conditions to be met with, are incomprehensible to one not familiar with the region, and form some excuse for the great waste of money in the buying of lands and working them during the earlier months. Travel was perforce on foot, and supplies were carried on men's backs through swamps and dense forests for many weary miles. The range of vision is limited in the bushes, and the mantle of glacial drift conceals the rocks, especially the flat formations of the Mesabi. It is no wonder then that a narrow belt of ore should remain undiscovered for so many years in the vast region stretching between Duluth and the Giant's range. Few explorers were hardy and persistent enough to spend the time and undergo the hardships involved in a long search for ore on the much-condemned range. Even after the discovery of large deposits of fine ore it is a matter of great difficulty and expense to take men and supplies into the new regions twelve to forty miles from any railroad. It is highly important that good wagon roads be built through this mining region at once. The roads at present are almost impassable, and the cost of transporting mining outfits enormous, while the delay is a serious matter in many instances. It is a matter of interest to the entire state to have these new ore fields developed, and the first thing to be done is to construct passable roads.

## EXTENT OF THE RANGE.

The ore formation of the Mesabi range extends from the Canadian boundary line in Minnesota, in a direction a little south of west to and beyond the Mississippi river in township 56–25, a distance of 140 miles or more. Part of this distance the ore-bearing rocks are concealed from sight by the later gabbro overflow.

The width of the ore belt at any one place probably does not exceed two miles, and will be found to be generally less than one. The ore lies in nearly flat beds, having a variable depth or thickness up to 100 feet. It is not to be inferred that there is a continuous belt of ore half a mile to a mile or more wide and 40–80 feet thick extending for 140 miles on this range. That would be far from true. The ore deposits are found at intervals over this area where the conditions necessary for their formation and accumulation exist. What these conditions are will be explained later. The ore on the eastern end of the range is hard, black and magnetic, all probably owing to the heat of the gabbro overflow. On the central and western portions of the range the ore is soft hematite, limonite and gœthite with hard hematite and limonite streaks of variable thickness.

Ore in merchantable quantity has already been found—June, 1892—on the central part of the range in seven townships, over a length of forty miles. There is good reason to believe it will be found in many places where no work has been done yet, as well as in some sections where hasty or misdirected exploration has so far failed to find it. Township 58-17 especially is likely to produce many more mines.

## EXTENT OF OTHER RANGES.

The iron mines worked on the Vermilion range at present are at two points only, Tower and Ely, twenty-three miles apart. Other lake Superior ranges have an extent as follows:

Marquette, from Goose lake to Three lakes, thirty-four miles.

Menominee, from the Breen mine to the Nanaimo, fifty miles.

Penokee-Gogebic, from Sunday lake to Upson on the Wisconsin Central R. R., thirty miles or less.

It is thus evident that there is an opportunity on the Mesabi range, considering merely the area of the iron formation, for a much larger quantity of iron ore than on any other range in the lake Superior district, which is admitted to be the greatest iron district of the globe.

In favorable situations the ore deposits on the Mesabi may have a width of a mile and a length of two miles. The width of ore-bodies here corresponds to the depth on other ranges. Hence there may be in one ore deposit on the Mesabi as much ore within one hundred feet of the surface as on the Vermilion or Marquette range down to the depth of one mile. When this idea is once comprehended and its truth admitted the great advantage of this new range over all other known ranges is at once recognized.

There is always the possibility that the ores of the Mesabi will be found to extend indefinitely to the south under the black slates of the Animikie, and even under the gabbro and trap rocks of the lake Superior basin, until it reappears in the Penokee-Gogebic range on the south shore. In that case the supply of iron which may be counted on for future production is simply incomprehensible and inexhaustible. The greatest and deepest mines of the world will be developed here, and the industry of iron mining and manufacture in this state will continue to grow until iron is no more an article of consumption.

But, while we admit this possibility, we must confess that we do not consider it likely to be the case. The nature of the ore, its probable method of origin as explained later on, its porous texture and hydrated composition, combined with our general geoscopy, force us to the opinion that the merchantable ore beds are narrow and only locally developed. If here and there ore is found at a considerable depth under the black slates it will be due to some local conditions which cannot be expected to prevail over a wide region, and will be correspondingly accounted for.

## GEOLOGY OF THE MESABI RANGE.

The geology of the Mesabi has been discussed in the various annual reports of the Minnesota survey which have described field work in the northern part of the state. The U. S. geological survey has also added considerable to the literature of the range and its geology. The views of different geologists, as expressed in these and other publications, will be found referred to in the report on "The Iron Ores of Minnesota," Bulletin No. 6, Geol. and Nat. Hist. Sur. I shall here give merely an outline of the views entertained at present by myself.

## GEOGNOSY OF THE RANGE.

This iron range presents one of the most interesting chapters in the life-history of that part of the earth's crust which is embraced within the boundaries of Minnesota. We have here the phenomenon of a series of strata, wide-spread and of immense thickness, entirely confined to the south side of a range of granite and syenite hills. Although the country is at the present time much lower, no trace of the Mesabi range rocks has been reported north of the Giant's range granite in this state. The altitude of the various portions of the range is not the same. Elevations or depressions amounting to hundreds of feet have taken place, and the horizontal Taconic strata of the Mesabi have simply sunk or been elevated with the granite and schist which sustain them. On the southern slope of the granite range, whose summits form blue hills visible for thirty miles either south or north, there are accumulated strata of quartzytes, iron slates, quartz slates, cherts and argillytes with flows of gabbro and trap rocks thousands of feet in thickness. Yet only the gabbro eruptives appear to have extended north of the lofty Giant's range, and that very seldom. It is not credible that the Taconic strata once existed north of the granite and have since been entirely swept away by erosion—glacially or otherwise. The sharp, deep gorges in the folded crystalline and earthy schists of the Vermilion range, which lies at the foot of the Giant's range to the north, would surely retain some traces of sediments which formerly filled them. And if the huge granite range was such a protection for the soft ores and slates which lie on its southern slope as to leave those extensive deposits of soft iron ore, which are now being discovered just beneath the drift mantle, surely there would be some protection afforded to similar rocks by the lesser parallel ridges farther north, and some remnants of the slates would remain.

Look, too, at the difference in the topography on the two sides of the Giant's range, especially west of the gabbro sheet. On the north abrupt ridges and narrow gorges in the vertical eastward-trending folds of the Keewatin; on the south a smooth plain of black slates covered by till, sloping gently southward for fifty miles. North of the granite, on the Duluth and Iron Range railroad, rock-cuts are frequent; south of it, on the Duluth, Missabe and Northern, there is not a rock-cut for forty miles. These differences can be explained in only one way—the limitation of the early Taconic ocean by this granite shore.

## DATE OF THE GIANT'S RANGE UPLIFT.

An examination of the granite range, which lies just north of the Mesabi iron belt, makes it evident that the granite hills have been uplifted—undoubtedly without much accompanying metamorphism or other disturbance—since the superincumbent Taconic strata were deposited.

Proof of this is found in the vicinity of Birch lake. Here the quartzyte of the Taconic is seen north of the summit of the Giant's range, but 600 feet below, on the shores of the lake and still confined to the south of the granite belt.

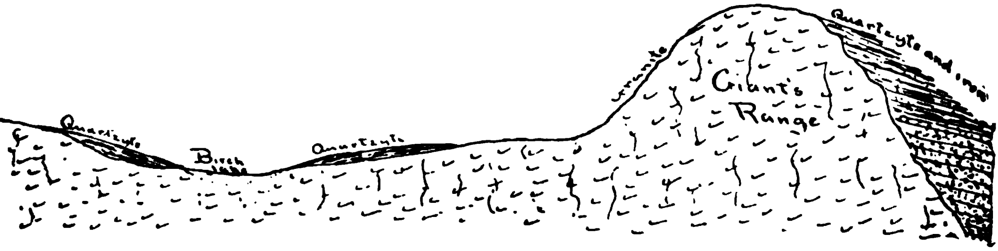

Fig. No. 1.—Section from Birch lake to the Mesabi range.

It has been remarked that the quartzyte and magnetite strata which lie on the granite south of Birch lake are almost up to the very summit of the Giant's range.* The force of the ice sheet must have been very strongly felt on this exposed ridge, and erosion would be carried to a greater depth here than elsewhere. The fact that the Taconic strata are still found in such an exposed situation is proof that the entire ridge was formerly covered by a considerable thickness of these rocks, and must have been elevated in that condition.

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*Seventeenth annual report Minn. Survey, p. 85.

At the same time it is true that the fact that the Taconic strata do not extend north of the Giant's range, is an indication that there was a ridge of some sort there during Taconic time. It thus appears probable that the entire region north of the granite may formerly have been higher than now—perhaps even higher than the granite ridge—and has since subsided to its present level. The elevation of the granite hills was thus accompanied by a depression both south and north.

### CAUSE OF THE GIANT'S RANGE UPLIFT.

In searching for an explanation of the gradual elevation of the Giant's range it is natural to look to the south, towards the lake basin, which is its apparent complement. The immense load of eruptive rock piled up on the north shore of lake Superior could scarcely fail to produce a sinking of the crust in that region. A depression in one part of the crust must be followed or accompanied by a corresponding change in contour and an elevation at some other place. Hence the most natural explanation of the hill range, which now forms the chief water-shed of Minnesota, is in the formation of the lake Superior basin and the outflow of great sheets of trap and gabbro.

These eruptions did not all occur at one time, part of them being found as inter-bedded or laccolitic sheets in the Taconic strata. The upward movement of the range was gradual, corresponding to the gradual accumulation of sediments and flows further south. There is not found in the quarzytes and slates, which now lie upon the granite hills at an elevation of fourteen hundred feet above the water of lake Superior, any stratigraphic deformation or mineralogic alteration which requires the supposition of rapid elevation. From this it follows that the petrographic nature of the Giant's range was practically the same as it is now, at the commencement of Taconic time. Metamorphism intense enough to produce the crystalline rocks of the range, would have had a similar effect on any strata resting upon them. But the slates and other rocks of the Mesabi do not show any evidence of metamorphosing agents aside from the superincumbent gabbro. The stratification is not destroyed, nor disturbed to any considerable extent, while the mineralogical changes observed are more likely to be the result of aqueous than of igneous action.

We have here a simple chain of reasoning from which to infer the solution of the as yet unsettled question of the stratigraphic position of the gabbro:

1st. The elevation of the Giant's range to its present position is post-Taconic.

2nd. The elevation of the Giant's range was caused by the gabbro, hence

3rd. The gabbro is post-Taconic.

This agrees with the observations and conclusions of R. D. Irving in the vicinity of Gunflint and Loon lakes. He has given a section south of these lakes which shows the olivine gabbro lying on top of the Animikie black slates and traps.[*]

## Order of Stratigraphy on the Mesabi.

The rocks exposed on the Mesabi are the following, in descending order:

| | | |
|---|---|---|
| 1. | Gabbro unconformable on all the following, | Taconic. |
| 2. | Black slates—Animikie, - - - - | Taconic. |
| 3. | Greenish siliceous slates and cherts, - | Taconic. |
| 4. | Iron ore and taconyte horizon, - - - | Taconic. |
| 5. | Quartzyte unconformable on 6 and 7, - | Taconic. |
| 6. | Green schists of the Keewatin, - - - | Archæan. |
| 7. | Granite or syenite of the Giant's range, | Archæan. |

It will be proper to give a brief description of the appearance and occurrence of each of these divisions. It is essential for economical exploration on the range, that these different rock horizons be recognized and distinguished from each other. The object of this sketch of the Mesabi range is more for the purpose of furnishing a reliable and simple account which will be understood and applied in future development, than a scientific discussion of the subject. To the explorer the difference between the green slates of the Taconic and the green schists of the Keewatin is of the utmost importance. The former lie, for the most part, above the ore horizon and the latter entirely beneath it. If he cannot distinguish them at sight he cannot tell which way to direct his line of test-pits, nor when to stop work in any one of them. If he calls the chert "quartzyte," and then concludes that he is below the ore because the quartzyte lies below it, he again makes a mistake and one which may be very costly or result in his missing his ore body entirely. Many similar instances have come under my observation. It is by determining such questions as these that geology aids the explorer and miner. Although an elementary knowledge of mineralogy and the composition of the more common rocks would assist in an understanding of the next few paragraphs, yet the principles laid down are so universal and the distinctions so obvious, that it is believed they can be understood and applied by anyone who reads them.

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[*] Seventh annual report, U. Geol. Sur., p. 421.

### 7. GRANITE OF THE GIANT'S RANGE.

The granite or syenite of the Giant's range lies north of the iron belt of the Mesabi. It forms high rounded ridges of pink or gray crystalline rock. It is composed of rather coarse crystalline grains of gray or flesh-colored feldspar, bluish translucent quartz and black mica or hornblende. It usually possesses no bedded structure and can be broken with almost equal ease in any direction. It is older than the rocks of the iron formation proper, and lies beneath them from the Mountain Iron mine westward. It has on the north a belt of crystalline mica and hornblende schists, and on the south seems to have a direct transition into

### 6. GREEN SCHISTS OF THE KEEWATIN.

These schists constitute the rock commonly called "greenstone," or "dioryte" by explorers. They are gray to green in color, softer than the granite and have an earthy appearance instead of a bright crystalline lustre like the mica schists. The green schist has a cleavage which is nearly vertical—when it is not massive. It never occurs in horizontal layers like the quartzyte and slate. The lower bed of the Mesabi ore formation, *i. e.*, the basal quartzyte,—always rests upon this Archæan green schist or upon the granite, and the nature and extent of the ore bodies seem to be entirely independent of the underlying rock.

The green schist does not always follow the course of the granite range. It diverges and forms minor ridges, uplifting the quarzyte and iron strata for a distance of several miles from the main ridge. The presence of these ridges of granite or green schists, whether exposed or not, is one of the essentials to the existence of a body of soft ore, as we shall see later. This green schist is the same as that of the Vermilion iron range, and it is not impossible that lenses of hard iron ore may be discovered in it in some place beneath the ore of the Mesabi. These schists are covered in many places by

## 5. QUARTZYTE UNCONFORMABLE ON THE SCHISTS AND GRANITE.

This rock is the lowest member of the Taconic strata which constitute the Mesabi iron formation. It is white, gray, green, pink or purple, and is composed of rounded grains of sand, mostly silica. It never has a high dip so far as seen on that portion of the range west of the gabbro overflow. Where it lies upon granite it is pink or white, or may be stained red by iron oxide. Where it rests on green schist it is finer grained, usually in thinner strata and gray or greenish in color. Near the bottom it often contains pebbles of quartz and granite, as well as jasper and greenstone. It has also been observed to contain white or pink mica in horizontal scales as large as half an inch across. In some thin sections the secondary enlargement of the quartz grains is well shown. In others the grains fit closely together and there are few interstitial spaces, although the quartz is crystalline. Where it is found in test-pits under the ore it has usually lost its character of hard vitreous quartzyte for some distance below the contact, and is a soft, coarse, crumbling sandstone, white or iron stained. No merchantable iron ore is found in or below this quartzyte, unless it should be in the green schist, and when this rock is encountered in a test-pit work should be discontinued as quickly as it would be in the granite or green schist. This quartzyte lies immediately under the taconyte horizon.

Its position with reference to the black slates has been a matter of some difference of opinion, and the writer formerly believed it to belong above them. There seems to be no question now, however, that this is the same as the Pewabic quartzyte at Gunflint lake and the Pokegama quartzyte of the Mississippi river, and that it is the lowest member of the Taconic. It has been assigned to the Cretaceous, Potsdam and Huronian by different geologists. Prof. N. H. Winchell believes it to be the equivalent of the Potsdam quartzyte of New York. It occurs at Sioux Falls, South Dakota, and at Baraboo, Wisconsin, in similar association with underlying granite and overlying iron bearing rocks.

## 4. IRON ORE AND TACONYTE HORIZON.

Resting immediately upon the basal quartzyte, and apparently conformable with it, is a series of strata which present very different appearances in different localities, and which constitute the iron ore deposits in situations favorable for their accumulation. These strata consist of siliceous and sometimes calcareous rocks banded with oxide of iron or iron ore. The ore occurs in streaks or beds of indefinite length and thickness. It is sometimes magnetite, sometimes hematite, hard or soft. The rock which encloses these bands may be called a jaspery quartzyte, but it contains much besides silica. It is of various colors, but usually gray. It is occasionally cherty, often brecciated and sometimes conglomeritic. There are layers of jasper having a peculiar mottled and streamed appearance; there are others of fine quartz grains more or less mingled with grains of iron oxide; others again are so fine grained as to be flinty, with amorphous silica, which evinces great readiness to dissolve and leave cavities or soft porous streaks in the ledge. In its fresh gray condition one portion of it does not present macroscopically individualized constituents. The silica is clouded with some grayish or greenish element which appears to contain a percentage of lime or iron carbonate. This rock is widely spread over the whole length of the Mesabi, and being different from anything found elsewhere and peculiar to this horizon of the Taconic, has been called *taconyte* by the writer. It has not been studied microscopally or chemically as yet. The examination of specimens now on hand will probably yield further interesting information as to its nature and origin.

This banded jaspery quartzyte or taconyte horizon is not of great thickness. There is a rather abrupt transition below into quartzyte, but a more gradual one into the siliceous slate and chert member above.

The percentage of iron in this rock as it occurs unaltered is seldom sufficient to make it a merchantable ore, though there may be found layers of ore in it thick enough to work profitably like those west of Gunflint lake in T. 65–4. It is not to be expected that there will be any mines of magnetic ore on the central portion of the range. The taconyte, however, is found in all degrees of alteration into good iron ore. The nature of this alteration will be explained later. It is only necessary to add here that this is the horizon to follow in the search for ore. It is the rock which contains and produces the ore, and test-pits which reveal this member of the Taconic formation are not discouraging. Having found it the next thing is to find some uniform, even slope of considerable descent and let the test-pits follow it down, be it north, east, south or west.

### 3. GREENISH SILICEOUS SLATES AND CHERTS.

These strata constitute a sort of transition stage between the rocks of the iron horizon and the black slates. There is no proof of any unconformity either above or below this member, but lithologically it is distinct from the rest. There is a considerable mixture of greenish material, apparently of eruptive origin, either intimately mixed with the silica and fine argillaceous matter or in separate streaks. Even the extremely siliceous cherts which constitute the upper part of this horizon occasionally present a greenish appearance due to intermixture with this basic element. There is sometimes found a layer of dense but soft black argillyte in this zone, which seems to be an indication of the great thickness of similar rocks to be deposited later.

The chert is red, yellow, black, white or green, and in the Thunder Bay region has a thickness of two or three hundred feet. It is not known how thick it is on the central Mesabi. It is not strictly confined to this member of the Taconic, but is occasionally found as low as the basal quartzyte, and above high up in the slates. Its content of silica varies greatly. Now it will have the appearance of pure translucent chalcedony, and again it is mixed with oxide of iron or some carbonate of lime and iron. It frequently possesses a peculiar brecciated appearance, having been thoroughly shattered into angular fragments which are re-cemented by the same amorphous silica.

This angular fracturing or jointing is also visible in the iron ore, even when it is soft enough to excavate with pick and shovel. It is more difficult to account for the large amount of silica in these cherts, which lie above the iron ore horizon, than for that which has enlarged and cemented the grains of the quartzyte below the ore. In the latter case the silica has been removed in carbonated solutions from the ferriferous layers down into the quartzyte and there deposited. How it came to be accumulated in such quantity at the chert horizon is a matter for future study. When the explorer finds this flinty slate formation it is safe to conclude that he is above the ore horizon (that is, above where the ore is, if there is any there) and must go deeper or farther *up* the general slope of the region.

### 2. ANIMIKIE BLACK SLATES.

The upper slaty strata of the last division soon pass into this, which, so far as examined on the central part of the range, consists entirely of several hundred feet of carbonaceous argillytes. Diamond drill records do not show the presence of the interbedded traps which are seen in the same horizon around Gunflint lake and eastward. It is possible that these eruptives may be higher up in these slates and will be discovered by future drilling farther south. These slates have the usual dip of the entire Taconic series on the

Mesabi, viz., from horizontal to 20° to the south or southeast. The dip is locally as high as 45° in some of the ore deposits where they lie close to the green schist.

These slates are supposed to extend southward under the gabbro to the St. Louis river, and then to appear again with a high dip and somewhat distorted stratification. If the St. Louis river slates are Animikie, as supposed, it is quite likely that the lower horizon of iron ore and quartzyte may also come to the surface in the same vicinity, and thus still another iron range may be discovered, still nearer Duluth. It is obvious, however, that with the high dip of the St. Louis slates the ore deposits would soon lead to deep mining and lose the advantages which the Mesabi possesses in lying in flat deposits.

The practical inference to be drawn from black slate outcrops on the Mesabi is that they are always *above* the iron ore horizon, and surface exploration must be pursued in the direction contrary to the dip.

The task of test-pitting through the black slates is almost a hopeless one, for the dip is sufficient to make a depth of several thousand feet in a few miles. In case of diamond drilling, where the property is all within the slate area, the only general advice is to get as near the north side of the property as possible, for if there is any ore under the slate it will be found in a shorter vertical distance there than farther south.

### 1. GABBRO.

This rock is sometimes called "granite" by explorers. I have heard some of them say that there is granite on both sides of the ore belt in 59-14. But the average explorer knows the difference between granite and gabbro. Granite has a pink color and contains crystalline grains of lavender blue quartz, together with mica or hornblende.

Gabbro is gray—seldom if ever pink, and contains no free quartz. It is almost wholly composed of gray feldspar (labradorite), which has pearly and often striated cleavage planes and is softer than quartz. The hills south of the iron belt in 58-16 are composed of this gabbro, which probably lies above the black slates and underlying iron rocks. The gabbro poured out of the earth's surface like lava and flowed north over the surface of the country, tipping the rocks up on edge and sometimes floating along huge slabs of the Taconic strata several hundred feet long, which are now found standing at various angles surrounded by the cooled gabbro.

From Birch lake eastward for several miles the gabbro flowed so far north as to cover the iron belt completely and we now find it lying on the granite. The effect of the heat of this molten gabbro was to make the iron ore, which already existed in the rocks, hard and magnetic, and this effect seems to have been felt for miles away from the edge of the gabbro.

Other minerals besides iron were changed by the same agency, and even so hard a rock as the quartzyte was so changed that samples of it have recently been designated "altered gabbro" by an eastern petrographer.

There is good reason to believe that the iron ore deposits in their present condition have been formed principally since the gabbro overflow. There was a certain amount of iron in the rocks originally, but this has been greatly augmented and concentrated in more recent times.

Accompanying the gabbro is frequently more or less black magnetic ore, which carries an injurious amount of titanic acid. This black ore occurs in grains in the rock nearly everywhere, and sometimes forms large deposits. It has a dull lustre and is not finely granular like the magnetite of the Taconic strata. It also lacks the evidences of stratification everywhere visible in the quartzyte and associated ores.

The northern and western boundaries of this gabbro sheet are approximately shown on the geological map accompanying Bulletin No. 6 of the geological survey. It will there be seen that there is no trace of this rock known west of range 16, and it is to be expected that the slates will be found immediately under the glacial drift west of the gabbro. The ore also loses its magnetic quality as we approach the Mississippi river, and at Prairie river it is nearly all hematite.

Although parties of explorers have recently gone into the gabbro area on Partridge river, equipped for test-pitting, it is scarcely necessary to say that there is no good reason to expect merchantable iron ore deposits in or under this eruptive flow in any place but along the northern edge, where it covers the ore belt. Farther south it reaches a thickness of hundreds of feet, and the slates below are still hundreds of feet above the ore horizon.

The advice in general is: Keep away from the gabbro. The ore found under it will be magnetic, may be titaniferous and is sure to be mixed with lean siliceous portions which will interfere with cheap mining.

## OCCURRENCE OF THE ORE.

In the foregoing pages it has already been indicated how the ore occurs. Among explorers and miners on the range there is great confusion of ideas on this point. It is said to be in veins, and many are still searching for a hanging wall and predicting that the flat portions occurring without one, are what they term "slop-overs." It is quite common to be told that the vein will soon take a high dip to the south and go down at an angle of 60°, more or less, to a great depth. Those who entertain this opinion go still farther and look for the continuation of the "vein" to an indefinite distance across the country in one direction. The proper direction is often rather absurdly ascertained by drawing a line through the locations of two or more mines on the map and extending it across adjacent property for miles. The amount of money already spent in extremely unpromising locations that have been selected in this way would buy several good mines. Others say that the ore is a surface "wash" which has settled in waters of very recent date in troughs or valleys. Still again it is said that the ores are eruptive, and the shiny limonite coating in some cavities is pointed to as unmistakable evidence of fusion and rapid cooling.

The most ancient of ideas is held by some that the ore deposits date from the creation of the world, and those who hold this idea say wisely: "Where it is there it is, and you cannot see any further into the ground than any of us, nor tell us where the ore is likely to occur." It would be extremely rash to deny the truth of the old Cornish saying, but repeated experience has proven that a knowledge of the geology of a region will and does enable us to tell where the ore *probably* exists and where it does not.

The occurrence of the Mesabi ores is not in veins or lodes. No hanging and foot wall proper are to be found. The deposits lie on quartzyte, and for convenience that may be called the foot wall, but it has not the same significance nor does it bear the same relation to the ore body that a true foot wall bears to a true vein. In rare instances the ore will be found with a "capping" of jaspery quartzyte or taconyte varying in thickness from a few inches to thirty feet or more. This will be called a hanging wall, but not properly. Moreover, the course of the ore deposits is not persistent in one direction unless the slope of the ridge on which they lie has a straight trend. The soft ore bodies follow the slopes, and when they change direction the ore deposit usually either comes to an end or changes also. This can be seen at several places, but especially marked at the Mountain Iron mine. The ore first discovered lies in a horse-shoe basin, the sides of which are high and have a steep slope. The ore follows the side of this basin and is discovered in pits which follow the slope around to the northwest, as well as on a subordinate ridge which runs south and southeast for half a mile. There is no principle more universal on the range than this: the presence or absence of an ore body depends on the presence or absence of an elevation, on the slope of which the proper horizon of Taconic strata occurs. This idea will be further explained in discussing the origin of the ore.

The ore deposits are not likely to assume a high dip and thus to extend to great depths. On the contrary, as we go south away from the granite and green schist ridges, the entire formation flattens down and the dip is hardly perceptible. This fact is not indicative of the existence of soft ore deposits under the slates at great distances south from the iron belt, as at present defined.

The ideas of surface "wash" and eruptive flows are also necessarily discarded. The existence of oceanic stratification and the frequent transition from soft ore into the rock strata of the ancient Taconic are alone sufficient to disprove both of these ideas. Moreover, there is no trace of the chemical action which would have taken place if the ores were eruptions, nor does the physical character of the ore harmonize with this idea. The deposition of limonite in shiny coatings in crevices and elsewhere, is by the action of aqueous solutions, and instead of being an indication of heat is just the reverse.

## ORE DEPOSITS OCCUR IN BEDS.

The Mesabi ore deposits are in regular *beds*. They constitute part of the Taconic strata and are still in almost their original position. They are part of the horizon which lies next above the basal quartzyte. They grade into the rocks of this horizon in all directions laterally, and occasionally both above and below. As a rule, however, the ore lies directly on the softened and disintegrated basal quartzyte which does not contain much iron oxide. The bedding planes of the original strata are perfectly preserved in the ore, as are the joints and even the differences in texture of the various layers of jasper, chert, coarse and fine taconyte and slate.

The ore deposits thus far discovered on the Mesabi, with few exceptions, lie just below the glacial till, which varies in depth from a few inches to one hundred feet. The ore body has a depth equally as great, and usually is wedge-shaped with the narrow end or side lying toward the top of the slope and the thickest portion farther down. There may be occasionally a knoll or ridge of jaspery quartzyte lying above the surface plane of the slope. In this case the ore generally passes under the knoll, which thus forms a capping; but occasionally this hard knoll or ridge extends downward unaltered to the basal quartzyte and constitutes a "horse" in the ore body. These "horses" are called "dykes" by some explorers. They are not true dykes, however, but parts of the general formation which do not cut through the quartzyte below the ore, as eruptive dykes would.

True dykes are not common along the range, and their absence constitutes one of the chief points of difference between the Mesabi and the Penokee-Gogebic. The accumulation of the Mesabi ores cannot be due in any way to dykes, for there are none associated with the ore, and no ore where dykes are found. This fact indicates that perhaps the ore deposits on the Penokee-Gogebic, instead of being produced through the agency of the dykes in forming troughs in which the ore was deposited, have been formed *in spite* of the dykes and would have been much deeper and more extensive had it not been for them. From what can be seen on the Mesabi, dykes and even troughs are unnecessary features, the ore being due to a replacement and concentration process which has proceeded on all uninterrupted slopes of sufficient pitch where the proper rocks exist for such a change. This operation or process of replacement, moreover, extended as far down the slope as the local conditions have permitted since the rocks were elevated to their present position. If the slope was a long one, and in the shape of a large basin, the ore deposit is large. If it was narrow or interrupted by numerous gorges or ridges, the ore is apt to be limited in quantity and of poorer quality. Where there was an opportunity for the greatest freedom of drainage and the most extensive percolation of solutions through the rocks for a considerable thickness, and over a considerable area, there are found the purest and largest accumulations of ore.

It is quite possible that there may be in places two or more parallel lenses of ore separated by ridges of unaltered taconyte. This might easily occur where the taconyte horizon is uncovered over a considerable area and where the surface consists of an undulating succession of ridges with gradual slopes. The usual dip of the Taconic rocks on the Mesabi is so slight that it does not always exceed the general slope of the surface of the country south of the Giant's range. For this reason there may occasionally be a succession of elevations, on the sides of which are ore deposits; and since the elevated portions of these ridges are usually magnetitic and the ore bodies are not, a dip needle may be used to advantage in locating the ore. Fig. 2 illustrates this idea.

The nature of the lateral and lower boundaries of the ore deposits will be more or less a matter of speculation until some are mined out. The extensive developments and the large production of ore already arranged for, promise interesting revelations within the next two or three years. At the present time, however, some idea of the appearance of the open pits, when the ore has been mined out, can be gained from a consideration of its mode of occurrence, as already known.

The upper edge is generally thin and rather the poorest ore. If this part of the ore is stripped and taken out it will leave the basal quartzyte exposed, dipping south at an angle of 10° to 40°. The lower side of the ore bed is more or less mixed with sand from this quartzyte. Hence the bottom of the open pits will be an almost plane surface dipping as the quartzyte dips, and at a short distance resembling soft ore more than quartzyte. The ore will gradually deteriorate below a certain depth in all pits and in an excavation until it becomes too poor to be mined.

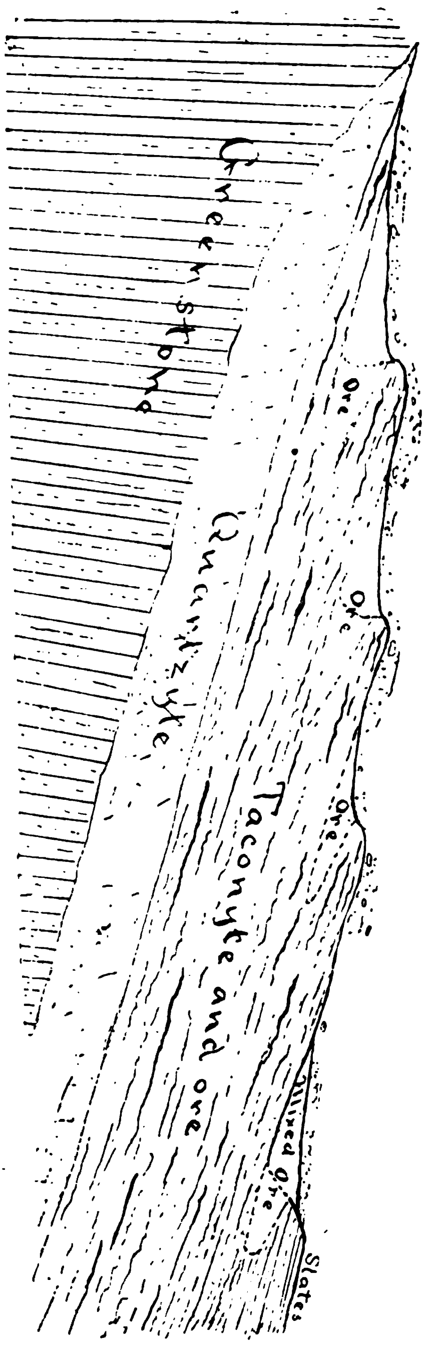


Fig. 2. Possible method of occurrence of parallel lenses of ore.

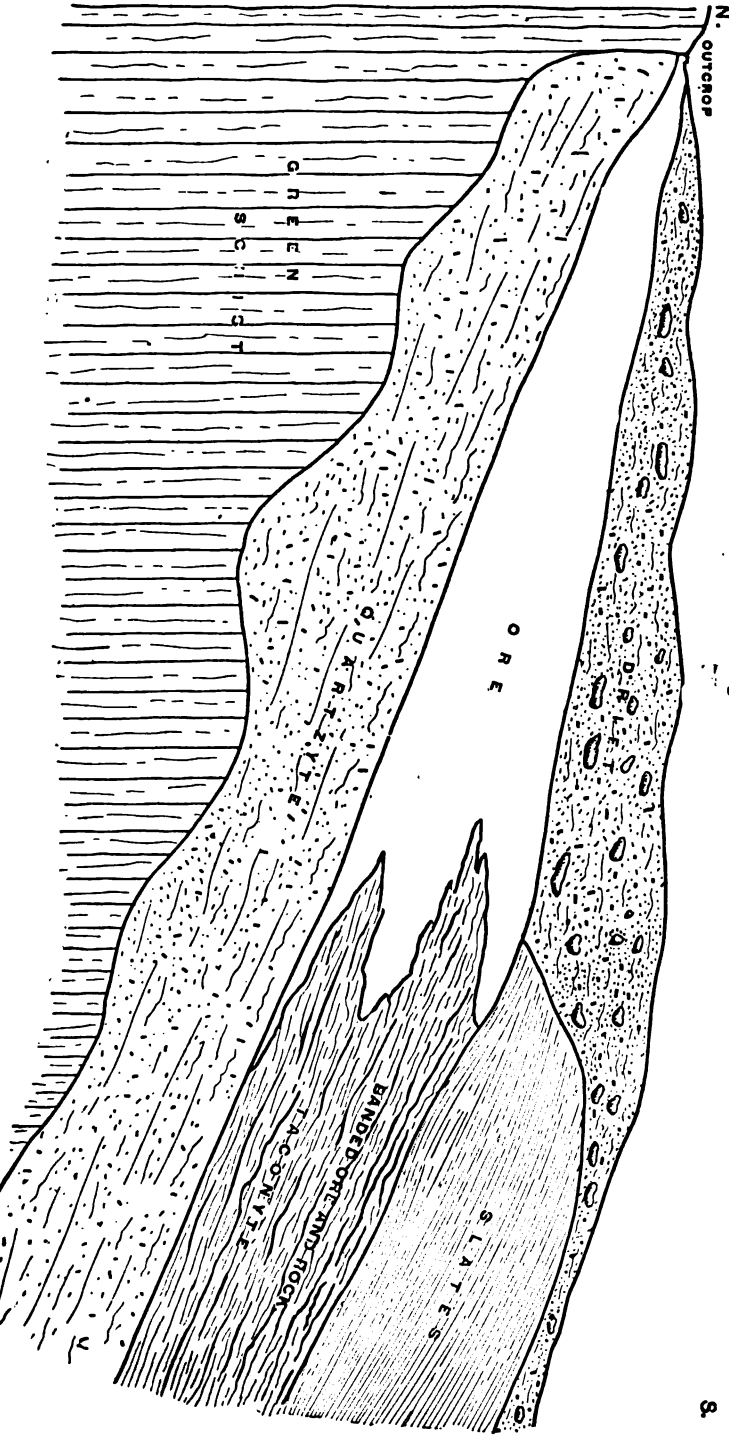
The sides of the ore bodies will present rather abrupt transitions into the jaspery quartzyte of the iron ore and taconyte horizon. It is not to be supposed that the limits of the soft ore will be marked by a wall or definite boundary plane on any side or at the lowest edge. It is rather to be believed that the ore extends into the rocks in sheets of variable thickness, and that when followed up and mined out, the lower edge of the remaining open pit will have a very ragged appearance something like the following, figure 3.

The ore on the lower, thicker edge may also be expected to deteriorate and become more like paint rock and earthy than the lower strata, which are mixed with sand. The capping or hard ridges already mentioned may present some interesting examples of the process of the replacement of silica by oxide of iron, which can be easily examined and studied when the surrounding ore is removed.

There are other interesting phenomena which can only be explained fully when the ore in their vicinity is removed. There appears to be a gorge on the Lone Jack and Missabe Mountain properties, excavated to the depth of sixty feet in the soft ore by some preglacial stream and subsequently filled with rounded, water-worn pebbles of hard ore. Test-pits on each side of this gorge filled with ore-gravel encounter fine, soft hematite just below the glacial drift, which does not here exceed twenty feet in depth. At the bottom of this ore gravel is a stratified layer or series of layers of white kaolin, more or less stained and mingled with fine red iron ore. This layer varies from a few inches to twelve feet in thickness and its true nature has not been ascertained. Below it is found the same blue hematite which occurs in the test-pits on both sides of the gorge sixty feet nearer the surface.

There are also gorges apparently scraped out by solid ice and filled by sand and gravel. On the Berringer forty, sec. 4, 58–16, a test-pit seventy-two feet deep has been sunk at the edge of one of these gorges. The east half of the pit passes down through soft blue hematite from the depth of forty-eight to seventy-two feet, while the west half of the pit is sand and gravel for the same distance. The wall of the ore is nearly perpendicular and seems to have been planed off. A short distance farther west there is a test-pit nearly one hundred feet deep, which did not strike anything but glacial till. These facts are an indication that the soft ore was essentially in its present condition at the time of the last glacial epoch.

Fig. 3.



GENERAL SECTION AT BIWABIK, SHOWING RELATION OF ORE TO SURROUNDING ROCKS.

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## VARIETIES OF MESABI IRON ORE.

### MAGNETITE.

The ore of the eastern portion of the Mesabi probably owes its magnetic properties to the heat of the gabbro overflow upon the hematites which were deposited in the rocks at the time of their formation in the oceanic waters.

Where this ore is associated with the lower beds of the Taconic it is rather coarsely granular and shiny. The ore which occurs higher up in the horizon is fine grained and compact, having a high specific gravity. Individual samples of this ore show a high percentage of iron and a low content of phosphorus and sulphur. Unfortunately it seldom occurs in beds of sufficient depth to render it valuable without concentration.

It is noticeable that there is a small percentage of magnetic grains in the blue-black, soft, granular hematite of the central portion of the range. A magnet will pick out grains from a handful of this ore from almost any test-pit in which it occurs. Its presence adds somewhat to the percentage of iron in the ore and does not produce any deleterious effect.

Small streaks of black, shiny, crumbling grains were noticed first in the test-pits on the Cincinnati property. They were at once seen to be magnetite, but their occurrence at the depth of sixty feet in solid strata of limonite and hematite was a surprise. The only well known means of producing magnetism in oxide of iron is by a considerable degree of heat. It is evident that it would be impossible to apply heat to a particular streak a couple of inches thick in the depths of such a deposit as that without also heating adjacent strata. Had the heat come from above all that portion of the deposit lying above this particular layer would also be affected by it. Had it been heated in some way from below there would be no hydrated ore left below it.

There are three possible hypotheses:

1. There may be some way to render ores magnetic aside from heating them.
2. This streak may have been heated and magnetized after deposition in its present position before the adjacent strata had their present chemical composition.
3. The ore may have been deposited here as magnetite originally.

In the Tenth Annual Report of the U. S. Geological Survey Prof. Van Hise has advanced the idea of the formation of magnetites by chemical processes during the oxidation and concentration of iron carbonates. He supposes that in the presence of an insufficient amount of oxygen, siderite may have been altered directly into magnetite. As a proof of this he mentions the fact that some of the magnetite is pseudo-morphous after siderite, and also that the hematite and magnetite are intimately mingled in the rocks of the Penokee-Gogebic range. He even states that it is exceedingly probable that all the magnetite is of secondary origin by chemical alteration of siderite at a low temperature.

In the case of the Mesabi magnetites we may admit that a portion of the magnetic grains may have been produced in this way. It is, however, not admitted that it is wholly due to such action. There are abundant evidences that much of this iron ore is an original constituent of the rocks, as siderite, magnetite, or sesquioxide of iron, probably the latter. The effect of a gabbro overflow would certainly be to render this original ore magnetic, if it were not already so, and less liable to chemical decomposition than the hematite and limonite. The magnetic oxide of iron is its most stable natural compound. It is often found unchanged by atmospheric agencies in exposed situations where other minerals have been deeply eroded and considerably decomposed. While the oxidation of magnetite into hematite is possible and has been observed in certain localities, it is not so common as the series of changes from siderite through limonite and hematite to magnetite. The pseudomorphs of magnetite after siderite mentioned above may be hematite pseudomorphs rendered magnetic by heat.

One difficulty in the way of an acceptance of the idea of this method of the formation of magnetite on the Mesabi is the fact that the magnetic strata are found near the surface of the ground where all chemical changes for a great space of time have been accompanied by an abundance of oxygen. Prof. Van Hise supposes that hundreds of feet, perhaps even thousands, of solid rock have been removed by erosion above the present surface on the Penokee-Gogebic range. There is strong evidence that no such depth of erosion has taken place on the Mesabi. The iron ore beds are essentially surface products, and do not occur under any great thickness of rock strata. The principal agent of erosion is glacial action. The freshness of glacial striæ and the drift mantle covering the rocks show that no postglacial erosion has taken place, and it is not likely that preglacial erosion was conducted to such a great depth. Moreover, it is only by the exposure of the very strata now found at and near the surface during all the ages since the gabbro overflow, that such extensive alteration deposits can be accounted for. Hence, unless the presence of some powerful reducing agent can be proven, the magnetic element of the rocks must be explained in some way which admits the presence of an excess of oxygen. It is not known at present whether the magnetite extends to any depth under the slates southward or not. All the facts we possess indicate that it does not. The heat of the gabbro cannot be supposed to account for the existence of magnetic ore in the rocks twenty miles or more distant. It may be that simple surface weathering of long duration is able to produce magnetic oxide from sesqui-oxide. It cannot be derived from a carbonate, for the resultant of surface alteration of siderite is always a sesqui-oxide. Admitting, then, that further study is necessary to account for the magnetic strata in the rocks between the Mountain Iron mine and the Mississippi river, we must still affirm our belief that the magnetic streaks in the pits of the Cincinnati represent ore that was originally deposited in the rocks as a hydrated sesqui-oxide and was rendered magnetic by the gabbro overflow. These streaks represent all the iron there was in the rocks at that time. The effect of the gabbro eruption was to elevate the Giant's range, and from that time until the present the process of ore deposition in these rocks by the decomposition of carbonates, if any were present, and the replacement of silica by ferric oxides, has been progressing. The result has been the formation of large deposits of pure ore in which the magnetite layers are interbedded with the more recent non-magnetic ores.

*The titaniferous magnetites* have already been mentioned. They occur in the gabbro, and are valueless at present. Their manner of occurrence and chemical composition are described fully in Bulletin No. 6, Minn. Geol. Surv.

### GŒTHITE.

This ore is the first to be found below the glacial drift in many test pits on the Hale, Kanawha, Cincinnati, Canton and Biwabik. It is soft, homogeneous yellow ore and occurs in layers several (six to twenty) feet in thickness. It was at first called limonite, but its high percentage of iron, as revealed by several analyses, together with the large amount of combined water showed that it is gœthite. As a rule it is non-bessemer. It is called "yellow ochre" by the miners and is frequently thrown out as poor ore. Its composition when absolutely pure is sesqui-oxide of iron 89.9, water 10.1, metallic iron 62.9. It occurs in such large quantities on this range that the term "Mesabite" may appropriately be applied to it to distinguish it in the iron trade. The following analyses show its purity:

Berringer yellow ochre, Iron 60.65, Phos. .070.

Canton yellow ochre, Iron 60.65, $SiO_2$ 2.09, Phos. .105, Comb. $H_2O$ 8.04. Free $H_2O$ 9.86.

Canton yellow ochre, Iron 60.75, $SiO_2$ 1.85, Phos. .065, Comb. $H_2O$ 10.05. Free $H_2O$ 12.77.

Canton yellow ochre, Iron 60.90, $SiO_2$ 4.85, Phos. .029. Some analyses indicate 61.5 per cent. of iron.

This ore will perhaps be of more value for the manufacture of mineral paints than for use in the furnace. It can be obtained cheaply and in large quantities.

## LIMONITE.

Hard masses and layers of brown hematite are found in many pits on the Mesabi. The ore is inclined to be siliceous and rather high in phosphorus. Many cavities are lined or filled with grape and pipe limonite ore. It seems to occur in portions of the ore bodies where considerable streams of water flow, continually or at certain seasons of the year, through the rocks and ore. Only a small percentum of all the ore in any mine so far discovered has been shown to be of this mineral. It is perhaps the least valuable of any except the titaniferous ores on the range.

## HEMATITE.

By far the larger part of Mesabi ores are hematites, as the term is used by mineralogists, *i. e.*, anhydrous sesqui-oxide of iron, whether hard or soft, crystalline, massive or earthy, red, blue, purple, brown, green or black. All varieties and all textures occur on this new range. The variation in appearance is remarkable, but the uniformity of composition is equally so. It is only after considerable experience in the ores of the range, and a careful examination of each variety by a hand-glass that the ore expert can tell which ore is the best and approximate its percentage of superior excellence. To be sure there are high and low grade ores here as on any other range, but samples of ores of at least ten totally different macroscopic characteristics can be selected that will not vary two per cent. in iron content. The process of ore formation here has been a discriminating and selective process, and has progressed regardless of color, hardness or texture.

The best grade of hematite is the blue-black soft ore found at many of the mines. Where this ore is in perfectly crystalline grains which possess little adherence to each other and will not "pack" in one s hand as do the more earthy ores, the percentage of iron reaches almost absolute purity. One sample of thirty feet of this ore from pit No. 15 on the Biwabik, taken by E. P. Jennings, yielded an analysis of 67.90 per cent. iron, 1.8 per cent. silica and

.016 per cent. phosphorus. Such ore as that is not excelled anywhere. It is this exceedingly pure ore that brings up the average of Mesabi ores. Without it there are several properties which would be non-bessemer; with it they are a good bessemer.

The general order of succession of the various kinds of ore is indicated by the plates of sections (Plates I, II, III, IV, V) from the Biwabik, furnished me by Mr. Jno. T. Jones and P. L. Kimberley.

### MANGANIFEROUS ORES.

Black oxide of manganese is found in hard and soft streaks in the ore of many mines on the range. As yet it has not been found in sufficient quantities to guarantee any considerable production of manganese ore or manganiferous iron ore. It will be strange, however, if some such ore is not produced from the range, since so many indications are met with, and the conditions are so favorable for its accumulation. Moreover, such ore is mined in limited quantity on the Penokee-Gogebic range, which is the undoubted equivalent of the Mesabi.

## ORIGIN OF MESABI ORES.

In Bulletin No. 6, on the Iron Ores of Minnesota, the idea was advanced that the bands of ore found interstratified with the Taconic rocks of the Mesabi are due to oceanic precipitation as hydrated sesqui-oxides at the time the sediments were deposited. Subsequent pressure and heat are supposed to have dehydrated the ores and the gabbro outburst to have rendered them magnetic. This idea is still maintained and has been strengthened by recent observations. But it accounts for only one portion of the Mesabi ores. Those original bands of iron were of limited thickness and were interstratified with rock material. The ore deposits recently discovered have none of these rock strata left. They were either never present or have been removed. On page 146 of the report referred to above is also found the following statement:

"We are quite ready at this time to adopt the theory that has been referred to originating with Prof. Edward Hitchcock, and more recently adopted by Prof. J. D. Dana and Prof. R. D. Irving, that these carbonated beds may be changed, and have been, on a large scale in the Taconic rocks of New England and of the Penokee-Gogebic range, by infiltrating waters, that their alkaline constituent has been carried away and their iron has been redeposited or concentrated in a residual condition as ferric oxides, and that by this concentration large beds of iron ore have been formed. It is because of this that we state our belief that possibly important beds of limonite or hematite, originating in this way, may yet be found in the Taconic region of Minnesota, the parallel of those that have recently been opened up in northern Wisconsin." This is a partial statement of the theory adopted by the writer for the ore deposits under discussion. From careful personal examination of the work on all parts of the Mesabi during its entire process of development, the idea has become stronger and more firmly fixed in his mind that these deposits are mainly due to chemical alteraation and replacement of some mineral by oxide of iron. There is a general harmony of facts and phenomena observed which go to support this idea, and which apparently are not in consonance with any other theory. The usual conditions existent at the different mines on the range, so far as they have been exploited, are the following :

1. There is a deposit of ore situated on some hill-side or in some basin.

2. This ore is regularly stratified.

3. The planes of stratification dipping less than 30° pass from the ore into and through the banded jaspery quartzyte or taconyte horizon in three directions and occasionally on all four sides.

4. The ore strata correspond in texture with the rock strata which appear to be their continuation.

5. Underlying the ore is usually a quartzyte horizon.

6. Just beneath the ore this quartzyte is decomposed into a crumbling sandstone, but it becomes vitreous a few feet below.

7. This quartzyte is impervious and presents an absolute barrier to surface infiltration. This fact is shown (1) by microscopic examination of the vitreous quartzyte, (2) by test-pits sunk into it, (3) by the large amount of surface water in the ore as the boundary between the ore and quartzyte is approached. The ore is porous and permits the water to filter through it. Test-pits are sunk through dry ore to the depth of nearly one hundred feet, where the ore body covers a considerable area, but water in large quantity is invariably encountered a few feet above the quartzyte.

Exceptional occurrences which tend still further to prove the replacement theory are, (1) the existence of deposits of half ferrified rocks with ore in bands and in isolated centers of deposition. In such situations the process of ore production, or natural manufacture, so to speak, can be observed in all stages of progression. (2) The occurrence of knolls of taconyte lying on top of the ore deposits, having been above the course of the chemical percolations, and thus having remained unaltered.

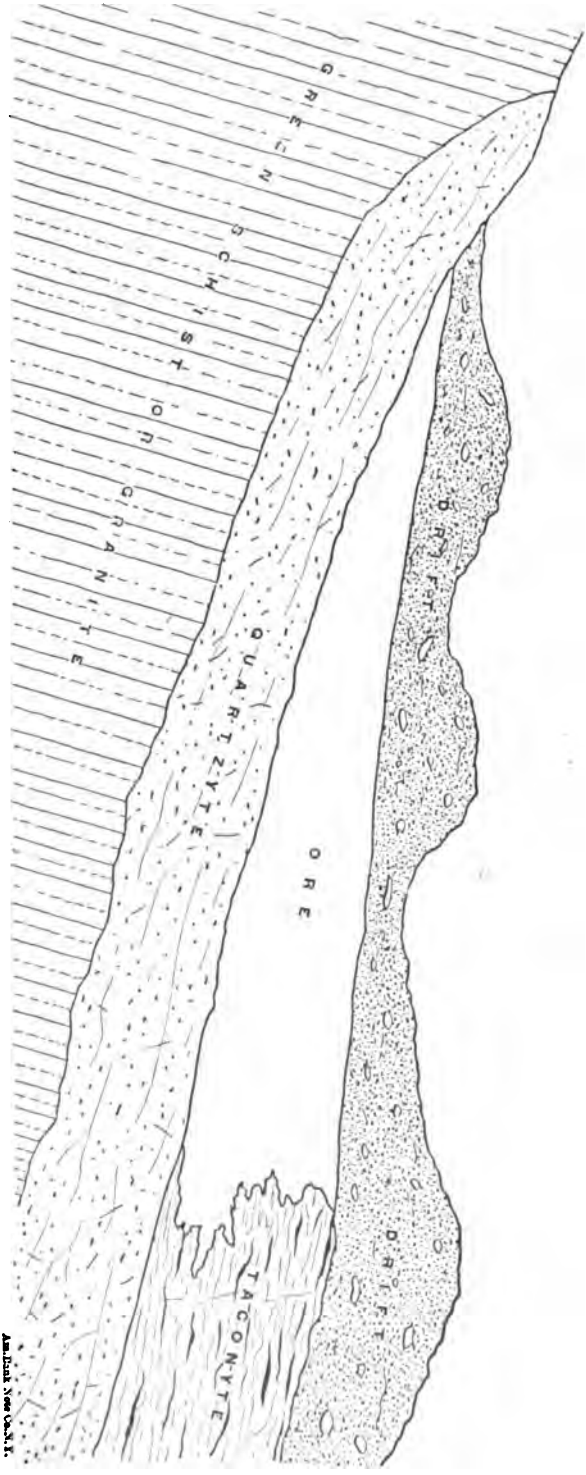
It is a fact confirmed by abundant observation that the iron ore occurs precisely at the taconyte horizon. It lies neither above nor below it, but in it and of it. It is natural that the process of this transformation into ore should be limited by the local environments. If the angle of the slope down which surface waters have flowed be too steep or too flat there is no resultant ore body, if it is moderate the ore deposit may have been produced to a great depth and width. If the basal quartzyte comes to the surface at the upper side of the slope the atmospheric waters appear to have flowed down along the line of separation between the taconyte and quartzyte. In this case it may happen that the process of replacement extended but a short distance above the quartzyte and there may be an unaltered capping of taconyte above the ore. If the hill side and top are covered with the jaspery quartzyte and banded ore formation the infiltrating waters sometimes seem to have worked a change downward into these rocks and there may or may not be an unaltered remnant of the taconyte horizon below, according to the original thickness and the natural facilities for chemical action.

There is even a third case seen on the Chicago property, in which a body of soft ore nine feet thick has been produced in the taconyte formation, and is seen graduating into the hard banded rock on all sides.

The process of replacement is of two or three varieties. Certain strata seem to be more easily ferrified than others, and instances are common where the wavy line of ferruginization is seen encroaching upon the blue or gray unaltered taconyte. This may often be followed in a single hand sample from taconyte to ore, while the stratification, texture and often appearance remain the same. The remarkable part of it is that all the original mineral elements have gone and the result is such pure oxide of iron. There is much silica of a chalcedonic or amorphous nature in the taconyte, and occasionally layers of quartzyte, but all these can be observed in the actual process of replacement by iron ore.

On the Cincinnati property it even appears that some of the basal quartzyte has been replaced by iron oxide. Samples taken from here show a complete transition from quartzyte to iron ore. In some of the intermediate samples the individual grains can be seen in all stages of removal. There are many encased in a shell of hematite, which can be seen increasing in thickness until on breaking the black grain no white silica grain is found. It has all been removed. With a specimen of this sort in hand it is impossible to doubt that here is an instance of the removal of silica and its replacement by sesqui-oxide of iron.

Fig. 4.



USUAL OCCURRENCE OF ORE BELOW DRIFT AND RESTING ON QUARTZYTE

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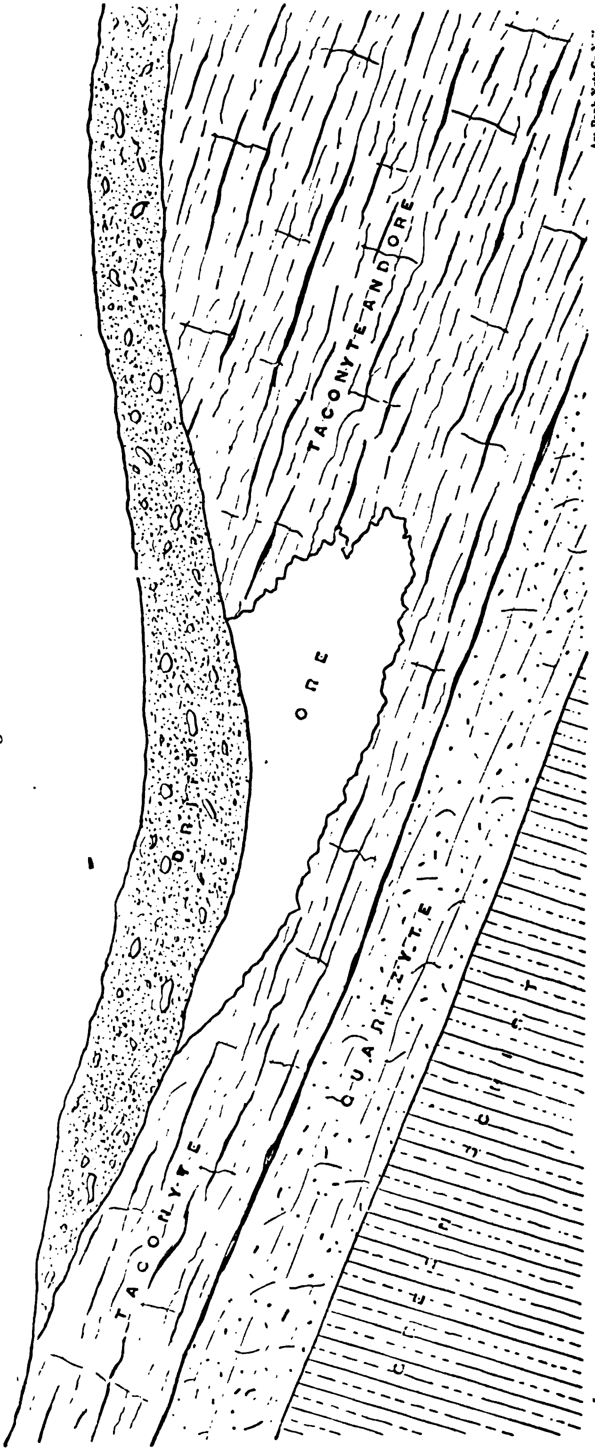

Fig. 5.

POSSIBLE METHOD OF OCCURRENCE OF ORE ON TACONYTE

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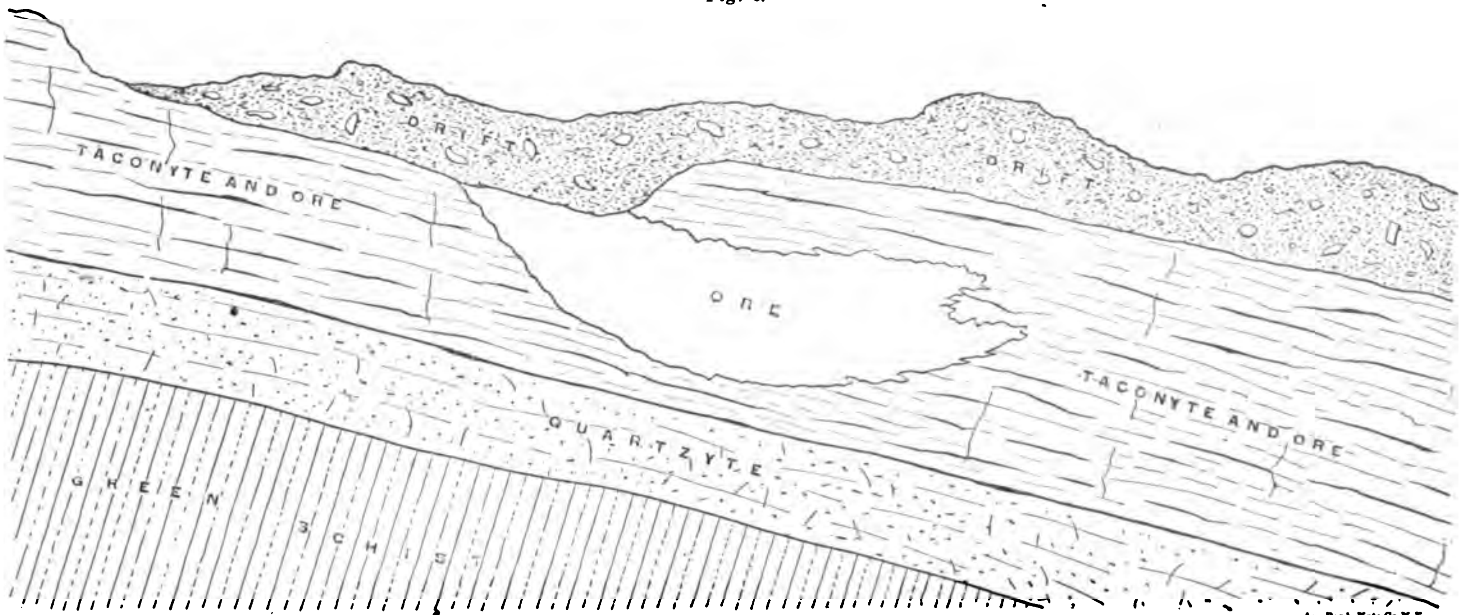
Fig. 6.



Possible Occurrence of Ore surrounded by Taconyte and Ore.

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Still another proof is found in the nature of the transition back again from ore to the taconyte on the lower edge of the deposits.

This has already been referred to under the head of "Mode of Occurrence of the Ore." If this ore be not a replacement product it must continue underneath the rocks belonging higher up in the formation and will ultimately be mined to a great depth. There is no absolute proof that this is not so. On the Biwabik and Cincinnati, however, the ore is seen to degenerate and pass into a low grade ore and then into "paint rock" and finally into the regular banded taconyte horizon on the southern edge.

There have been reports of the discovery of soft ore at great depths under the slates to the south of the present deposits, but these reports are not as yet authenticated. Even if they should be at one or two places in the basins of lakes like the Embarrass it would not weaken the replacement theory. For it is only natural that the effect of a body of water pressing downward through and into a series of soft slates would have some softening, oxidizing and disintegrating effect. The carbon of the graphitic slates would be dissolved and silica removed by it so that replacement deposits might be formed in such a place even at a depth of five hundred feet. It should be mentioned, moreover, that the glacial drift exceeds one hundred feet in depth on the southeast shore of Embarrass lake and may be twice as deep in the lake basin. This would make the actual depth from surface influences very much less and increase the likelihood of an ore deposit.

In searching for an explanation of this process of replacement we are met with many puzzling questions, and it is just as well to admit that more study is necessary for their solution. What started this process? How could so much quartz be removed? What has become of it? Where did all the iron come from? These and many other questions have presented themselves time and again.

It has been advocated that the iron ore of the Gogebic range was originally in the form of a carbonate which in the process of oxidation yielded the necessary solvent for the quartz. We find some traces of carbonates of lime and iron in the Mesabi rocks, but it does not appear in sufficient quantity to permit the assumption that the ore was originally a carbonate. There are not yet discovered any considerable non-oxidized carbonaceous portions of the rocks associated with the ores, except in the more recent slates of the Animikie, which are now found further south. It does seem probable, however, that the solvent for the silica was carbonic acid in aqueous solution, and its early source may have been (1) the atmosphere, (2) the black slates, which may have covered the ore horizon at one time and have since been eroded. (3) More recently decaying vegetation must have supplied a considerable amount.

The amount of carbonic acid gas in the atmosphere at the beginning of Silurian time is stated by different writers to have been far greater than at present. It is supposed that the Carboniferous was a period of dense atmospheres and warm temperatures. Dana states that in Archæan time the effects of carbonic acid must have been much greater than now owing to its much larger proportion in the atmosphere, and that it has gradually diminished in quantity up to the present time. He states after Hunt that the excessive proportion of carbonic acid in the atmosphere was the most efficient of all agents in rock destruction. Manual of Geology, p. 156. T. S. Hunt states that "all carbonates of lime, whether directly formed by the decay of calcareous silicates or indirectly through the intervention of carbonates of manganese, or alkalies, derive their carbonic dioxide from the atmosphere. The same must be said for the dolomites, magnesites and siderites, * * * the earth contains fixed in the form of carbonates, a quantity of carbonic dioxide, which if liberated in a gaseous form, would be equal in weight to one hundred if not two hundred atmospheres like the present." Min. Phys., pp. 37-38. Here, then, may be the explanation of the removal of silica in such large quantity. If the rocks which produced the present iron ore deposits have been uplifted and exposed to surface action since primordial time, the carbonic dioxide used in the removal of silica must have been derived, at least in part, from the atmosphere. This process would have been carried on to a considerable depth, and may have produced an appreciable effect, even below several hundred feet of sediments which may have since been eroded.

But if these iron bearing strata were ever covered by the slates which belong above them, we can find an abundance of carbon in these very black slates, and though it is not now in the form of carbonates, yet the action of surface waters would be such as to extract sufficient to make a carbonic acid solution powerful enough to take iron and silica into solution. Moreover, Hunt says "the removal of silica in soluble form does not depend on the intervention of alkalies." And the carbon in the graphitic Animikie slates may have been at earlier times in some form more readily taken into solution. Having thus hinted at an answer to the first two or three questions which naturally arise in this connection, let us consider another one.

What has become of all the silica supposed to have been removed from the present location of the iron ores?

The answer to this is short. It was re-deposited in the rocks lying below and farther down the slope. (1) There is need of a source for an enormous amount of silica which has been added to the grains of quartz in the quartzyte, making it vitreous and filling all interstitial spaces. (2) There are considerable amounts of chalcedonic and flinty silica found associated with the quartzyte, and in the other rocks associated with the ores. This silica may be largely from a different source, but it may be partially derived from the leaching of the ore beds. (3) There are deposits of silica in all the cracks and fissures of the slates which lie at a lower elevation but stratigraphically above the ore horizon. Test-pits, for instance, on the Rouchleau, south of the Biwabik, encountered black slates and found no ore. These slates had been more or less jointed and the joints were filled by a bluish silica, sometimes mammillated, sometimes drusy. It is apparent to an observer that the most natural source for this silica is in the ore deposits farther up the hill to the north. Future researches will throw more light on this subject, and will perhaps show other ways in which the removed silica has been re-deposited.

As for the source of the iron, it is believed to have been largely the result of oceanic deposition, both chemical and mechanical, and to have been simply concentrated in its present situations.

There was also a removal of iron in solution. It was brought down to supply the places whence the silica was taken. These solutions followed the natural drainage courses. Elevation of the strata produced general jointing. The rocks on top of an elevated knoll were cracked full of joints, and the waters had free and abundant opportunity to percolate downward even in some places where the slope was not sufficient to accomplish it otherwise. The iron now being mined may formerly have been disseminated through rocks now completely removed by erosion.

## QUALITY OF MESABI IRON ORE.

For some unknown reason the opinion prevailed for several months after the discovery of many of the best mines on the range, that the ore was of inferior quality. This may have been due to false reports purposely circulated by those who had no desire to see a new range discovered and exploited in competition with the mines in which they were interested; or it may have been due to honest but incorrect sampling. Each addition to the family of lake Superior iron ranges is received more unkindly by the older brothers and sisters. Dame Nature seems to have bestowed her best favors on her youngest children. The Vermilion, Gogebic and Mesabi ranges have each in turn revealed newer and greater riches. It was with extreme reluctance that the proprietors of mines in other districts recognized the importance of the Mesabi. Indeed they have not yet done so, nor will they until next year, when the ore finds its way to the markets and furnaces of the East.

It is true that the first test-pits were sunk on the thin upper edge of the ore, and the upper strata are not so rich as those lower and farther down the slope on which the deposits lie. The analyses first obtained, however, were sufficient to convince an unprejudiced person of the importance of the new district. The average of a large number of samples taken in January and February, 1892, indicated that the ore would yield about sixty per cent. metallic iron and that seventy-five per cent. of it would be within the bessemer limit as to phosphorus. Since then the test-pits have been increased in depth and number and the quality of the ore taken out has improved, as will be seen from the analyses which follow. There has been still further improvement since these samples were taken.

## METHOD OF SAMPLING.

The most reliable samples are "pit samples." The usual method of obtaining them is by standing in a barrel or bucket, pick in hand, and while being lowered from the top to dig out a groove in the side of the pit from top to bottom, letting the ore fall into the barrel. Upon reaching the top the ore is broken into small fragments if it is not already fine, and carefully mixed and quartered down to a sample of eight or ten pounds. Taken in this way the samples should fairly represent the ore that will be shipped from that pit. All the hard layers must be grooved out as deeply as the soft ones, for the percentage of iron may vary; and, of course, sand streaks must be included, for they cannot be eliminated in mining. It is remarked by all new-comers that the ore has a sandy appearance and feel. There are occasional small streaks of sand in it, and near the bottom small grains of white silica are common, and can be seen by a hand glass. Analyses are surprising to these ore experts as revealing but a small per cent. of silica. The sandy feel is due to the nature of the ore, which is largely made up of crystalline grains of hematite.

The habit, quite general on the range, of dumping successive bucket-fulls of ore on a circular stockpile and spreading it around evenly renders dump samples rather unreliable. It is evident that the last ore mined is on the top of the dump, and as it is not feasible to dig to the center of a dump twenty or thirty feet across, the sample taken will represent but a part of the ore penetrated by the pit. To be sure the sample is as likely to vary one way as the other, but it is not satisfactory unless the pit is quite uniform or the ore has been divided as it was taken out.

The following table of analyses does not do full justice to all of the mines represented. The Berringer, Canton, Lake Superior, Lone Jack and New England have already made developments showing a higher grade of ore, and there is no doubt that some of the others will improve with further development.

## ANALYSES OF MESABI IRON ORES.

### BERRINGER MINE.

| PIT NUMBER. | SAMPLER. | Iron. | Silica. | Phos. | Mang. | Comb. Water. | Free Water. |
|---|---|---|---|---|---|---|---|
| 0. | E. P. Jennings | 57.50 | 10.33 | .108 | | | |
| 4. First 10 ft. | J. A. Crowell | 60.70 | | .069 | | | |
| 4. | J. A. Crowell | 62.15 | | .049 | | | |
| 4. Dump | J. A. Crowell | 63.10 | | .032 | | | |
| 4. | W. J. Rattle | 61.90 | | .051 | | | |
| ?. Ochre | J. A. Crowell | 60.95 | | .070 | | | |
| ?. 60 ft. ore | E. P. Jennings | 59.20 | 4.41 | .111 | | | |
| 4. 35 ft. ore | E. P. Jennings | 62.60 | 3.58 | .049 | | | |
| Average | | 60.97 | 6.05 | .067 | | | |

### BIWABIK MINE.

| PIT NUMBER. | SAMPLER. | Iron. | Silica. | Phos. | Mang. | Comb. Water. | Free Water. |
|---|---|---|---|---|---|---|---|
| 1. Dump | J. T. Jones | 55.55 | 9.77 | .107 | | 6.64 | 12.21 |
| 1. 22 ft. ore | J. T. Jones | 58.25 | 4.49 | .112 | | 7.05 | 6.63 |
| 2. | D. H. Bacon | 60.32 | 5.07 | .121 | .37 | | 5.37 |
| 9. | P. L. Kimberley | 61.95 | 2.92 | .090 | | 6.48 | 7.50 |
| 11. | J. T. Jones | 61.05 | 4.42 | .075 | | 5.85 | 2.93 |
| 11. | D. H. Bacon | 61.44 | 3.59 | .076 | .17 | | 6.33 |
| 11. | W. J. Rattle | 61.50 | 4.01 | .075 | .957 | | |
| 11. | E. P. Jennings | 59.30 | 8.57 | .075 | | | |
| 11. | H. V. Winchell | 61.58 | 4.07 | .058 | .16 | 6.48 | 5.59 |
| 11. 58 ft. ore | J. T. Jones | 61.95 | 2.92 | .092 | | | 2.50 |
| 13. | P. L. Kimberley | 55.25 | 7.36 | .030 | | 6.25 | 11.85 |
| 15. Blue ore | J. T. Jones | 66.50 | 1.57 | .015 | .21 | | |
| 15 Upper 6 ft. | J. T. Jones | 67.90 | 1.23 | .010 | | | |
| 15. Lower 10 ft. | J. T. Jones | 66.60 | 2.04 | .012 | | | |
| 15. Whole pit | H. V. Winchell | 64.30 | 3.20 | .038 | .349 | | |
| 15. Blue ore | W. J. Rattle | 66.70 | 1.84 | .022 | .442 | | |
| 15. Brown ore | W. J. Rattle | 62.90 | 3.35 | .047 | .587 | | |
| 15. Red-brown | W. J. Rattle | 62.90 | 2.50 | .045 | .831 | | |
| 15. Selected | H. V. Winchell | 68.15 | 1.025 | .011 | | | |
| 15. 30 ft. blue | E. P. Jennings | 67.90 | 1.80 | .016 | | | |
| 15 *Drift | E. P. Jennings | 64.40 | 4.36 | .027 | | | |
| 15. *Drift | J. T. Jones | 65.80 | | .034 | | | |
| 15. Brown-blue | E. P. Jennings | 65.90 | 2.70 | .042 | | | |
| 15. | J. T. Jones | 67.50 | | .010 | | | |
| 15. First 20 ft. | J. A. Crowell | 61.85 | | .057 | | | |
| 15. Last 16 ft | J. A. Crowell | 63.20 | | .032 | | | |
| 15. 30 ft. blue | E. P. Jennings | 64.50 | | .018 | | | |
| 15. First 10 ft drift | J. A. Crowell | 67.25 | 1.88 | .010 | | | |
| 15. 0-20 ft. drift | J. A. Crowell | 67.00 | | .020 | | | |
| 15. 20-30 ft. drift | J. A. Crowell | 65.80 | | .034 | | | |
| 15. 30-40 ft. drift | J. A. Crowell | 66.20 | | .039 | | | |
| 15. 40-50 ft. drift | J. A. Crowell | 66.00 | | .038 | | | |
| 15. 70-80 ft. drift | J. A. Crowell | 66.50 | | .015 | | | |
| 15. 80-90 ft. drift | J. A. Crowell | 66.60 | | .012 | | | |

*From 150 foot drift at depth of sixty-five feet.

### BIWABIK MINE.—*Continued.*

| PIT NUMBER. | | SAMPLER. | Iron. | Silica. | Phos. | Mang. | Comb. Water. | Free Water. |
|---|---|---|---|---|---|---|---|---|
| 15. | 90-100 ft. drift | J. A. Crowell | 66.00 | | .015 | | | |
| 15. | 100-110 ft. drift | J. A. Crowell | 66 20 | | .013 | | | |
| 15. | Dump | H. M. Curry | 65 850 | 2.450 | .022 | .160 | 2.2 | |
| 17. | | J. T Jones | 63.25 | | .056 | | | |
| 17. | | J. T. Jones | 58.60 | | .069 | | | |
| 17. | Brown | E. P. Jennings | 63.40 | 5.04 | .031 | | | |
| 17. | 97-107 ft | J. T. Jones | 64.15 | | .023 | | | |
| 17. | 67-77 ft | J. T. Jones | 64 00 | | .026 | | | |
| 17. | | J. T. Jones | 63 25 | | .056 | | | |
| 17. | 72 ft. ore | J. T. Jones | 65.34 | | .035 | | | |
| 17. | 63 ft. ore | W. H. Smith | 67.20 | 1.27 | .017 | .130 | 2.06 | |
| 19. | 30 ft. ore, 56 ft. deep | H. M. Curry | 64 20 | 2.070 | .054 | .110 | 5.00 | |
| 19 | 18 ft hard ore and soft ore 96½ ft. down | H. M. Curry | 66.25 | 1.63 | .034 | .250 | 2.70 | |
| 19. | 2½ ft. brown ore at bottom | H. M. Curry | 64.75 | 1.450 | .072 | .290 | 5.67 | |
| 20. | | E. P. Jennings | 62.60 | 5.83 | .064 | | | |
| 20. | First 15 ft | J. T. Jones | 62.40 | | .065 | | | |
| 20. | 15-25 ft. | J. T. Jones | 62.40 | | .068 | | | |
| 21. | First 15 ft | J. T. Jones | 50 85 | | .097 | | | |
| 21. | 15-25 ft. | J. T. Jones | 62.50 | | .063 | | | |
| 21. | | E. P. Jennings | 57.40 | 11.04 | .093 | | | |
| 23. | Blue ore 7 ft. from bottom | H. M. Curry | 67.35 | 1.85 | .015 | .130 | 1.10 | |
| 24. | Bottom ore | H. M. Curry | 64.050 | 1 71 | .027 | .240 | 4.88 | |
| 25. | Dump ore, just under surface | H. M. Curry | 63.45 | 2.85 | .028 | .370 | 4 6 | |
| 26. | 37 ft. at base | H. M. Curry | 65.50 | 1.73 | .049 | .060 | 3.3 | |
| 26. | 5 ft. at bottom | H. M. Curry | 66 40 | 1 63 | .043 | .080 | 2.4 | |
| 26. | Blue ore at base | H. M. Curry | 63 25 | 2.75 | .042 | .300 | 3.1 | |
| | Average | | 63 70 | 3.46 | .0455 | .284 | 3.01 | 6·76 |

### CANTON MINE.

| PIT NUMBER. | | SAMPLER. | Iron. | Silica. | Phos. | Mang. | Comb. Water. | Free Water. |
|---|---|---|---|---|---|---|---|---|
| 3. | | D. H. Bacon | 57 22 | 7.47 | .083 | | | 9.50 |
| ... | North pit | D. H. Bacon | 63.13 | 2.29 | .030 | | | 7.65 |
| ?. | Yellow ochre | J. T. Jones | 60.65 | 2.09 | .105 | | 8 04 | 9.86 |
| ?. | 20 ft. sur., 45 ft. ore | J. T. Jones | 59 15 | 4.31 | .048 | | 9 21 | 10.22 |
| ?. | Yellow ochre | E. P. Jennings | 60.90 | 4.85 | .029 | | 10.05 | |
| | Average | | 60.21 | 4.20 | .059 | | 9.10 | 9.307 |

### CINCINNATI MINE.

| PIT NUMBER. | | SAMPLER. | Iron. | Silica. | Phos. | Mang. | Comb. Water. | Free Water. |
|---|---|---|---|---|---|---|---|---|
| 1. | "Poor ore" | P. L. Kimberley | 54.85 | 15.06 | .026 | | 2.35 | 8.09 |
| 2. | | J. T. Jones | 50.95 | 8 35 | .032 | | 3.16 | 8.44 |
| 2. | | W. J. Rattle | 60 10 | 8 60 | .040 | .475 | | |
| 3. | | J. T. Jones | 61.65 | 5.39 | .031 | | 3.24 | 4.80 |
| 3. | | W. J. Rattle | 59.80 | 8 40 | .040 | .497 | | |
| 3. | | H V. Winchell | 59.24 | 10.25 | .046 | | | 4.01 |
| 4. | | E. P. Jennings | 62.50 | 4 89 | .087 | | | |
| 5 | [Biwabik] | P. L. Kimberley | 63.00 | 3.84 | .029 | | 5.03 | 3.16 |
| 5. | [Biwabik] | W. J. Rattle | 61.50 | 4 83 | .039 | 1.98 | | |
| 5. | [Biwabik] | E P. Jennings | 63.50 | 5.37 | .039 | | | |
| 5. | [Biwabik] dump. | H. V. Winchell | 59.00 | 7.65 | .050 | | | |
| 7. | | W. J. Rattle | 57.80 | | .038 | | | |
| 8. | | E. P. Jennings | 54 50 | 14.13 | .028 | | | |
| 8. | | J T. Jones | 60.70 | 8.10 | .034 | | 2.85 | 10.96 |
| 8. | Dump | J. T. Jones | 58.50 | 8.90 | .045 | | 5.39 | 7.55 |
| 8. | | W. J. Rattle | 51.90 | 16.09 | .040 | .515 | | |
| 9. | | E P. Jennings | 54.40 | 14.13 | .028 | | | |
| 9. | | W. J. Rattle | 54.50 | 9.08 | .078 | .460 | | |
| 10. | | E. P. Jennings | 55.70 | 9.06 | .112 | | | |
| 10. | | W. J. Rattle | 55.10 | 8.68 | .110 | .810 | | |
| 10. | Dump | H. V. Winchell | 55 75 | 7.38 | .078 | | | |
| 12. | | E. P. Jennings | 56.80 | 6.00 | .063 | | | |
| ... | Second from north | E. P. Jennings | 57.20 | 12.88 | .034 | | | |
| | Average | | 58.30 | 8.95 | .0498 | .791 | 3.67 | 6.71 |

## GREAT WESTERN MINE.

| PIT NUMBER. | SAMPLER. | Iron. | Silica. | Phos. | Mang. | Comb. Water. | Free Water. |
|---|---|---|---|---|---|---|---|
| 4. | J. A. Nichols | 65.02 | | .024 | | | |
| 5. | J. A. Nichols | 63.71 | | .020 | | | |
| Average | | 64.36 | | .022 | | | |

## HALE MINE.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1. | D. H. Bacon | 61.16 | 2.89 | .063 | .40 | | 7.05 |
| 2. | W. J. Rattle | 61.48 | 3.60 | .068 | 1.20 | | |
| 3. | W. J. Rattle | 61.10 | 4.92 | .067 | .849 | | |
| 4. | W. J. Rattle | 62.10 | 2.92 | .075 | 1.29 | | |
| 5. | W. J. Rattle | 57.60 | 5.95 | .077 | 1.657 | | |
| Average | | 60.67 | 4.05 | .074 | 1.079 | | 7.05 |

## KANAWHA MINE.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2. | J. T. Jones | 64.45 | 3.32 | .050 | | 5.29 | 11.76 |
| 2. | W. J. Rattle | 60.65 | 4.90 | .051 | .644 | | |
| 3. | W. J. Rattle | 59.60 | 6.40 | .081 | .754 | | |
| 4. | W. J. Rattle | 59.10 | 7.48 | .084 | .405 | | |
| Average | | 60.95 | 5.52 | .066 | .600 | 5.29 | 11.76 |

## LONE JACK MINE.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1. | D. T. Adams | 59.415 | 7.55 | | .251 | 3.05 | |
| 1. Bottom | H. M. Curry | 58.565 | 6.75 | | .348 | 3.15 | |
| 1. | E. P. Jennings | 55.00 | 9.29 | .096 | | | |
| 2. | D. T. Adams | 60.806 | 4.78 | | .775 | 2.05 | |
| 2. Bottom ore, dump | H. M Curry | 60.225 | 3.716 | .089 | .540 | 2.08 | |
| Average | | 58.402 | 6.417 | .092 | .478 | 2.55 | |

## McKINLEY MINE.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1. | D. H. Bacon | 60.32 | 10.72 | .024 | .770 | | 1.89 |
| 2. | D. H. Bacon | 61.48 | 9.27 | .022 | | | 1.64 |
| ?. | J. M. Clifford | 65.60 | 4.10 | .017 | | | |
| Average | | 62.46 | 8.03 | .021 | .770 | | 1.76 |

## MISSABE MOUNTAIN MINE.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1. | J. T. Jones | 63.30 | 3.617 | .051 | | 1.85 | |
| 1. Upper 10 ft | H. M. Curry | 56.80 | 7.20 | .041 | .580 | 3.30 | |
| 1. [?] | J. T. Jones | 62.40 | 4.80 | .026 | .270 | 1.78 | 9.80 |
| 1. [?] | J. T. Jones | 62.89 | 3.38 | .061 | | 2.92 | |
| 1. | C. F. Howe | 65.21 | 3.83 | .037 | | 2.26 | |
| 1. 45 ft. ore | H. V. Winchell | 64.03 | 3.094 | .053 | .337 | 1.75 | 6.70 |
| 3. | H. M. Curry | 60.05 | 4.65 | .075 | 1.090 | 3.40 | |
| 3. Dump | W. H. Smith | 62.33 | 5.53 | .027 | .840 | 1.15 | |
| 4. Top of dump | H. M. Curry | 61.304 | 5.40 | | .503 | 5.10 | |
| 4. Dump | H. V. Winchell | 60.90 | 3.14 | .060 | | | |
| 5. Dump | H. M. Curry | 56.817 | 11.967 | .050 | .180 | 1.76 | |
| ?. | E. P. Jennings | 64.30 | 4.36 | .077 | | | |
| ?. | E. P. Jennings | 62.50 | 4.89 | .087 | | | |
| Average | | 61.73 | 5.066 | .055 | .542 | 2.52 | 8.25 |

MOUNTAIN IRON MINE.

| PIT NUMBER. | SAMPLER. | Iron. | Silica. | Phos. | Mang. | Comb. Water. | Free Water. |
|---|---|---|---|---|---|---|---|
| 1. [Old number] | D. H. Bacon | 62.43 | 5.70 | .047 | | | 4.15 |
| 2. [Old number] | D. H. Bacon | 59.12 | 11.48 | .048 | | | 2.74 |
| 1. [New number] | —Joyce | 65.60 | | .052 | | | |
| 2. [New number] | W. H. Smith | 62.250 | 6.820 | .038 | .116 | 2.50 | |
| 1. | Geo. Sutherland. | 63.98 | | .029 | | | |
| 2. 18 ft. ore | H. M. Curry | 57.68 | 13.35 | .054 | .130 | 2.20 | |
| 2. | Geo. Sutherland. | 66.19 | | .068 | | | |
| 3. 14 ft. ore | W. H. Smith | 64.93 | 3.70 | .057 | .238 | 1.88 | |
| 2. | L B. Miller | 61.90 | 5.82 | .048 | | | |
| 8. | H. M. Curry | 65.14 | 4.11 | .048 | | | |
| 3. | Geo. Sutherland. | 65.14 | | .048 | | | |
| 4. | H. M. Curry | 65.55 | 4.14 | .037 | | | |
| 4. | L. B. Miller | 65.00 | 3.51 | .033 | | | |
| 4. 23 ft. ore | H. M. Curry | 64.242 | 4.98 | .035 | .232 | 2.80 | |
| 6. | Geo. Sutherland. | 66.52 | | .031 | | | |
| 4. 18 ft. ore | W. H. Smith | 59.81 | 8.66 | .057 | .155 | 3.99 | |
| 7. | L. B. Miller | 65.30 | 3.08 | .053 | | | |
| ?. Lammers, Chem. | ?. | 63.68 | 6.77 | .041 | | | |
| 8. | L. B. Miller | 65.30 | 3.07 | .054 | | | |
| ?. Lammers, Chem. | ? | 62.52 | 2.74 | .031 | | | |
| 9. | L. B. Miller | 66.00 | 2 49 | .046 | | | |
| ?. Lammers, Chem. | ? | 62.65 | 5.20 | .056 | | | |
| Average | | 63.22 | 5.64 | .050 | .155 | 2.674 | 3.495 |
| NEW ENGLAND MINE. | | | | | | | |
| 1. 26 ft. ore | E. P. Jennings | 58.30 | 5.99 | .084 | | | |
| 2. | E. P. Jennings | 62.60 | 5.64 | .037 | | | |
| 3. 20 ft. ore. | E. P. Jennings | 61.80 | 6.44 | .029 | | | |
| Average | | 60.90 | 6.02 | .050 | | | |
| OHIO MINE. | | | | | | | |
| 3. | E. P. Jennings | 63.20 | 5.07 | .032 | | | |
| 3. Pit. last 20 ft. | J. T. Jones | 64.53 | 4.20 | .047 | .414 | 1.91 | |
| 4. 26 ft. ore | E. P. Jennings | 64.45 | 3.03 | .037 | | | |
| 8. Dump, last 20 ft. | J. T. Jones | 61.25 | 8.783 | .020 | .450 | 1 48 | |
| Average | | 63.16 | 5.34 | .036 | .432 | 1.695 | |
| Average of averages | | 61.46 | 5.92 | .0528 | .667 | 4.063 | 6.886 |

## COMPARISON WITH OTHER ORES.

Until there shall have been a large consumption of the Mesabi ores it will be impossible to tell exactly how they compare in all respects with the ore of other districts. There are high and low grades of ore on all ranges, and the average tonnage purity of an entire range has never been determined. By this is meant the average quality of the ore taking into consideration the number of tons of each grade mined. Some idea of the comparative excellence of Mesabi ores, however, can be gained by a consideration of the analyses already given and the actual results obtained in other instances.

The output of the Minnesota Iron Company from the Vermilion range in 1891 is classified in the following table. This ore is well-known as some of the finest hard hematite obtainable, and yet only forty-seven per cent. of the product was bessemer.

## TABLE SHOWING PRODUCT OF THE MINNESOTA IRON COMPANY IN 1891.

| SHAFT. | Vermilion. | Soudan. | Red Lake. | Minnesota. | Nipigon. | Total. |
|---|---|---|---|---|---|---|
| No. 1 | 2,813 | 24,379 | 6,581 | 14,615 | ......... | 48,388 |
| No. 3 | 298 | 10,939 | 1,065 | 46,382 | 546 | 59,330 |
| Alaska | ......... | ......... | 14,243 | ......... | ......... | 14,243 |
| No. 5* | ......... | 21,779 | 6,655 | 159,836 | 3,983 | 192,253 |
| No. 7 | ......... | 46,174 | 6.324 | 5,068 | ......... | 57,566 |
| No. 8 | 92,464 | 591 | 10,073 | ......... | ......... | 103,128 |
| No. 9 | 154 | 5,683 | 2,423 | 11,126 | 425 | 19,811 |
| No. 10 | ......... | 15,341 | 742 | ......... | ......... | 16,083 |
| No. 10 Scram | ......... | 1,177 | 82 | ......... | ......... | 1,259 |
| No. 17 | ......... | 377 | 834 | 676 | ......... | 1,887 |
| No. 13 | ......... | 2,319 | 913 | ......... | ......... | 3,232 |
| No. 12 | ......... | 21 | 91 | ......... | ......... | 112 |
| No. 19 | ......... | ......... | 278 | ......... | ......... | 278 |
| Total | 95,729 | 128,780 | 50,304 | 237,703 | 5,054 | 517,570 |

*Includes Montana, Butte, Armstrong and No. 6 Shaft.

Pickands, Mather and Co., the Cleveland agents for these grades of ore, give the following average analyses for 1891, and guarantees for 1892.

## COMMERCIAL GRADES OF ORE FROM VERMILION IRON RANGE, 1891.

| COMPOSITION. | Vermilion. | Soudan. | Red Lake. | Minnesota. | Chandler. | Long Lake. |
|---|---|---|---|---|---|---|
| Iron | 67.75 | 65.96 | 63.49 | 68.14 | 63.91 | 60.06 |
| Silica | 1.58 | 2.27 | 5.00 | 1.30 | 5 10 | 7.20 |
| Phosphorus | .157 | .102 | .111 | .049 | .041 | .044 |
| Manganese | .29 | .14 | .19 | trace | .69 | .61 |
| Alumina | .98 | 1.80 | .90 | 1.10 | 2.90 | 2.87 |
| Sulphur | trace | trace | .026 | trace | trace | .043 |
| Magnesia | trace | .30 | .30 | .13 | trace | .19 |
| Lime | 1.00 | .54 | .71 | .56 | .37 | .31 |
| GUARANTEES. | | | | | | |
| Iron | 66.66 | 65.00 | 62.00 | 66.66 | 63.00 | 60.00 |
| Phosphorus | ......... | .12 | ......... | .055 | .05 | .05 |

In 1891 the Chandler mine produced 354,993 tons of Chandler ore and 20,873 tons of Long Lake ore. The entire product of this mine is bessemer. In some respects this is the greatest mine in the world. Occupying but eighty acres its production for 1892 will be nearly 650,000 gross tons of remarkably uniform ore. Cargo after cargo is sampled at Cleveland that will not vary half of one per cent. in iron content. Under the able direction of Joseph Sellwood the cost of mining has been reduced to less than $1.00 per ton at the depth of 450 feet. It is believed that there is a profit of $1.00 per ton on this ore, providing it brings $4.85 at Cleveland, as it is said to have done in 1892. This estimate is based on the following details:

| | |
|---|---|
| Cost of Mining, - - - - - - - | $1.00 |
| Royalty, - - - - - - - - - - | .35 |
| R. R. Freight to Two Harbors, - - - | 1.00 |
| Lake Freight to Cleveland, - - - - - | 1.20 |
| Insurance, Commission, etc., - - - - | .25 |
| | $3.80 |

These figures are approximate and are given merely for the sake of indicating the entire feasibility of mining at a profit on the Mesabi, where the cost of mining will be considerably less than at the Chandler, with higher royalties.

The average of the analyses given of the Biwabik ore indicates that in quality it is nearly equal to the Chandler ore. If the expense of placing it on the car, including royalty, were equal, there would be a slight difference [equal to the freight from Ely to Tower, perhaps] in favor of the Biwabik. It might even be possible to sell the ore at $4.00 per ton and still have a nice profit. If in addition to this there are any other directions in which the Biwabik ore can be produced more cheaply than the Chandler, such as smaller mining cost, there is so much more profit. This point will be discussed later.

The analyses of certain standard grades of ore from the other lake Superior ranges is given in the following table.

## ANALYSES OF LAKE SUPERIOR IRON ORES.*

### MARQUETTE DISTRICT.

| NAME OF ORE. | Iron. | Phos. | Silica. | Mang. | Alum. | Magn. | Lime. | Sulphur. |
|---|---|---|---|---|---|---|---|---|
| American | 65.00 | 0.045 | 4.50 | ...... | ...... | ...... | ...... | ...... |
| Angeline—Hard | 65.50 | 0.069 | ...... | ...... | ...... | ...... | ...... | ...... |
| Angeline—Hematite | 66.36 | 0.062 | ...... | ...... | ...... | ...... | ...... | ...... |
| Barnum | 65.00 | 0.066 | 4.70 | 0.20 | 0.30 | 0.35 | trace | ...... |
| Buffalo | 62.33 | 0.130 | 6.90 | 0.37 | 1.61 | 0.96 | ...... | ...... |
| Cambria | 60.50 | 0.064 | 7.25 | 0.37 | 3.81 | 0.33 | 0.02 | 0.042 |
| Champion, No. 1 | 67.00 | 0.040 | 3.50 | ...... | ...... | ...... | ...... | ...... |
| Cleveland, No 1 | 65.60 | 0.104 | 3.05 | 0.21 | 0.99 | 0.18 | [illegible] | [illegible] |
| Cleveland Hematite | 60.00 | 0.060 | 6.74 | 0.63 | 2.35 | 0.12 | 0.12 | [illegible] |
| Cliff Shaft | 62.70 | 0.100 | 3.45 | 0.52 | 1.55 | 1.15 | 1.61 | 0.065 |
| Comrade | 60.50 | 0.100 | ...... | ...... | ...... | ...... | ...... | ...... |
| Detroit | 56.60 | 0.066 | 8.00 | ...... | ...... | ...... | ...... | ...... |
| East New York | 60.10 | 0.055 | 11.64 | 0.41 | 1.11 | 0.31 | 0.12 | [illegible] |
| Humboldt | 65.10 | 0.130 | 5.00 | 0.12 | 0.22 | 0.25 | 0.64 | [illegible] |
| Imperial | 57.50 | [illegible] | 5.30 | 0.03 | 1.71 | 0.41 | 1.16 | 0.065 |
| Jackson | 62.70 | [illegible] | ...... | ...... | ...... | ...... | ...... | ...... |
| Lake Superior, No. 1A | 64.00 | 0.115 | ...... | ...... | ...... | ...... | ...... | ...... |
| Lake Superior, Slate | 66.10 | [illegible] | 3.00 | 0.03 | 1.22 | 0.12 | 0.48 | 0.065 |
| Lillie | 56.96 | 0.064 | 6.60 | ...... | ...... | ...... | ...... | ...... |
| Lucy | 53.50 | 0.145 | 12.75 | 4.55 | ...... | ...... | ...... | ...... |
| Michigamme | 55.50 | 0.114 | 4.57 | 0.91 | 0.51 | 0.11 | [illegible] | [illegible] |
| Michigamme, No. 1 | 62.40 | 0.055 | 7.50 | 0.60 | 0.90 | 0.39 | 1.35 | [illegible] |
| Milwaukee | 62.16 | 0.166 | 4.32 | 0.45 | 0.60 | 0.90 | 1.10 | [illegible] |
| Mitchell | 59.96 | 0.131 | 6.56 | 0.62 | 1.35 | 0.30 | 0.42 | [illegible] |
| Negaunee | 60.00 | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| Prince of Wales | 62.56 | 0.106 | 5.51 | 0.37 | 1.70 | 0.17 | 0.50 | 0.053 |
| Prout | 53.72 | 0.141 | 17.65 | ...... | ...... | ...... | ...... | ...... |
| Queen | 62.96 | 0.112 | 4.65 | 0.41 | 1.11 | 0.31 | 0.12 | [illegible] |
| Republic, Magnetic | 68.77 | 0.161 | 1.75 | ...... | ...... | ...... | ...... | ...... |
| Republic, Specular | 67.50 | 0.043 | 3.71 | 0.24 | 0.95 | 0.06 | 0.41 | 0.012 |
| Salisbury Bess | 62.00 | 0.045 | 4.00 | 0.22 | 0.50 | 0.00 | 1.00 | 0.012 |
| Sharon | 61.90 | [illegible] | 8.00 | 0.12 | 0.72 | 0.36 | 0.84 | 0.012 |
| Sheffield | 61.00 | 0.115 | ...... | ...... | ...... | ...... | ...... | ...... |
| South Buffalo | 65.90 | 0.110 | 4.10 | 0.31 | 1.46 | 0.34 | 0.82 | [illegible] |
| Volunteer | [illegible] | [illegible] | ...... | ...... | ...... | ...... | ...... | ...... |
| Winthrop | 63.40 | 0.110 | 5.37 | 0.35 | 0.51 | 0.11 | 0.24 | [illegible] |
| Average | 62.33 | 0.079 | 4.72 | ...... | ...... | ...... | ...... | ...... |

### MENOMINEE DISTRICT.

| NAME OF ORE. | Iron. | Phos. | Silica. | Mang. | Alum. | Magn. | Lime. | Sulphur. |
|---|---|---|---|---|---|---|---|---|
| Aragon | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Armenia | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Chapin | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 2.71 | 0.81 | [illegible] |
| Commonwealth | [illegible] | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 0.62 | 0.78 | 0.041 |
| Crescent | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1.64 | 0.50 | ...... |
| [illegible] | [illegible] | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 0.97 | 0.036 |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | ...... | [illegible] | 0.91 | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1.18 | 0.041 |
| Great Western | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| Iron River | [illegible] | [illegible] | [illegible] | [illegible] | 3.41 | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | ...... | ...... | ...... | ...... |
| [illegible] | [illegible] | [illegible] | [illegible] | ...... | ...... | ...... | ...... | ...... |
| [illegible] | [illegible] | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1.10 | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | ...... | ...... | ...... | ...... | ...... |
| [illegible] River | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 5.58 | [illegible] |
| [illegible] | [illegible] | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| [illegible] | [illegible] | [illegible] | [illegible] | ...... | [illegible] | ...... | ...... | ...... |
| [illegible] | [illegible] | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| [illegible] | [illegible] | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | ...... | ...... | ...... | ...... |
| Average | [illegible] | [illegible] | [illegible] |  | ...... | ...... | ...... | ...... |

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*Geo. W. Goetz, Trans. Am. Inst. M. E. [illegible]

### VERMILION DISTRICT.

| NAME OF ORE. | Iron. | Phos. | Silica. | Mang. | Alum. | Magn. | Lime. | Sulphur. |
|---|---|---|---|---|---|---|---|---|
| Braddock | 65.17 | 0.052 | 4.50 | 0.13 | 0.48 | 0.16 | 0.56 | 0.020 |
| Chandler | 64.15 | 0.044 | 4.30 | 0.14 | 2.25 | 0.19 | 0.25 | 0.040 |
| Long Lake | 60.20 | 0.053 | 7.00 | 0.54 | 2.75 | 0.19 | 0.25 | 0.047 |
| Minnesota | 67.54 | 0.051 | 1.97 | 0.15 | 0.04 | 0.14 | 0.53 | 0.020 |
| Nipigon | 63.01 | 0.053 | 6.75 | 0.14 | 0.65 | 0.20 | 0.60 | trace |
| Red Lake | 62.86 | 0.099 | 6.95 | trace | 0.65 | 0.20 | 0.60 | trace |
| Soudan | 65.77 | 0.102 | 4.25 | 0.16 | 0.38 | 0.17 | 0.56 | 0.020 |
| Vermilion | 67.31 | 0.091 | 2.15 | 0.15 | 0.35 | 0.15 | 0.02 | ........ |
| Average | 64.50 | 0.068 | 4.46 | ........ | ........ | ........ | ........ | ........ |

### GOGEBIC DISTRICT.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Anvil | 61.54 | 0.053 | ........ | ........ | ........ | ........ | ........ | ........ |
| Ashland | 63.82 | 0.038 | ........ | ........ | ........ | ........ | ........ | ........ |
| Aurora | 63.36 | 0.034 | 4.00 | 0.03 | 1.98 | 0.12 | 0.04 | 0.033 |
| Brotherton | 62.50 | 0.037 | 6.13 | 0.49 | 2.98 | 0.39 | 0.16 | 0.070 |
| Cary | 58.84 | 0.062 | 5.20 | ........ | ........ | 3.66 | ........ | ........ |
| Eureka | 62.00 | 0.076 | 6.64 | 0.48 | 3.69 | 0.16 | 0.15 | 0.015 |
| Germania | 59.19 | 0.058 | ........ | ........ | ........ | ........ | ........ | ........ |
| Hennepin | 65.45 | 0.048 | 3.53 | 0.02 | 0.31 | 0.02 | 0.02 | 0.022 |
| Iron Belt | 62.75 | 0.042 | 6.33 | ........ | 2.44 | ........ | ........ | ........ |
| Ironton | 60.55 | 0.058 | ........ | ........ | ........ | ........ | ........ | ........ |
| Montreal | 64.22 | 0.053 | ........ | ........ | ........ | ........ | ........ | ........ |
| Mount Hope | 62.32 | 0.029 | ........ | ........ | ........ | ........ | ........ | ........ |
| Norrie | 63.72 | 0.043 | 3.40 | ........ | ........ | ........ | ........ | ........ |
| Pabst | 62.34 | 0.037 | 4.50 | ........ | ........ | ........ | ........ | ........ |
| Palms | 62.43 | 0.049 | ........ | ........ | ........ | ........ | ........ | ........ |
| Ruby | 62.50 | 0.045 | 4.20 | 0.49 | ........ | 0.16 | 0.45 | ........ |
| Section 33, North | 64.82 | 0.045 | ........ | ........ | ........ | ........ | ........ | ........ |
| Sunday Lake | 62.00 | 0.036 | ........ | ........ | ........ | ........ | ........ | ........ |
| Trezona | 62.55 | 0.061 | 4.44 | 0.02 | 0.97 | 0.03 | 0.02 | 0.031 |
| West Cary | 54.95 | 0.054 | 5.35 | 7.41 | ........ | ........ | ........ | ........ |
| Windsor | 62.00 | 0.051 | 6.30 | 0.81 | 3.45 | 0.31 | 0.40 | 0.025 |
| Average | 62.09 | 0.048 | 5.00 | ........ | ........ | ........ | ........ | ........ |
| Average of averages | 62.46 | 0.062 | 4.88 | ........ | ........ | ........ | ........ | ........ |

It will be noticed that the average of the grades given is higher in iron, but also higher in phosphorus than that of the large number of samples of Mesabi ore in the foregoing table. It is not claimed that this average is a correct one of the product of the ranges represented, but it is claimed that it is similar to the average obtained from the various Mesabi analyses, and the comparative high grade of the latter ores is shown thereby. It is unlikely that any ore will ever be shipped to Cleveland of as low grade as the lowest in the table, but it is certain that there will be grades of Mesabi ore as low in phosphorus and as high as or even higher in metallic iron than any hematite ore in the list, and that in large quantity.

It is hardly necessary to refer to the fact that southern ores are very much lower grade than lake Superior ores. Their proximity to the coal field and the furnace is the only feature that enables them to compete with the northern ores at present, and if an unlimited amount of high grade lake Superior ore can be profitably deposited in Cleveland at a reduction of fifty cents per ton below the present market price, most of the southern furnaces will be forced to suspend operations.

From recent experiments in New York and New Jersey it appears probable that a large amount of concentrated iron ore may be put upon the market in the next few years and become an active and important competitor of the lake Superior district. It is also reliably reported that the Sigua and Juragua districts of Cuba will soon ship several hundred thousand tons per annum of high grade ore to this country, and that they can do it at a profit with the present duty of 75 cents per ton. When shipped to this country for manufacture and exportation, foreign ores may obtain a rebate of the tariff paid for importation. This will be done to a considerable extent in the future.

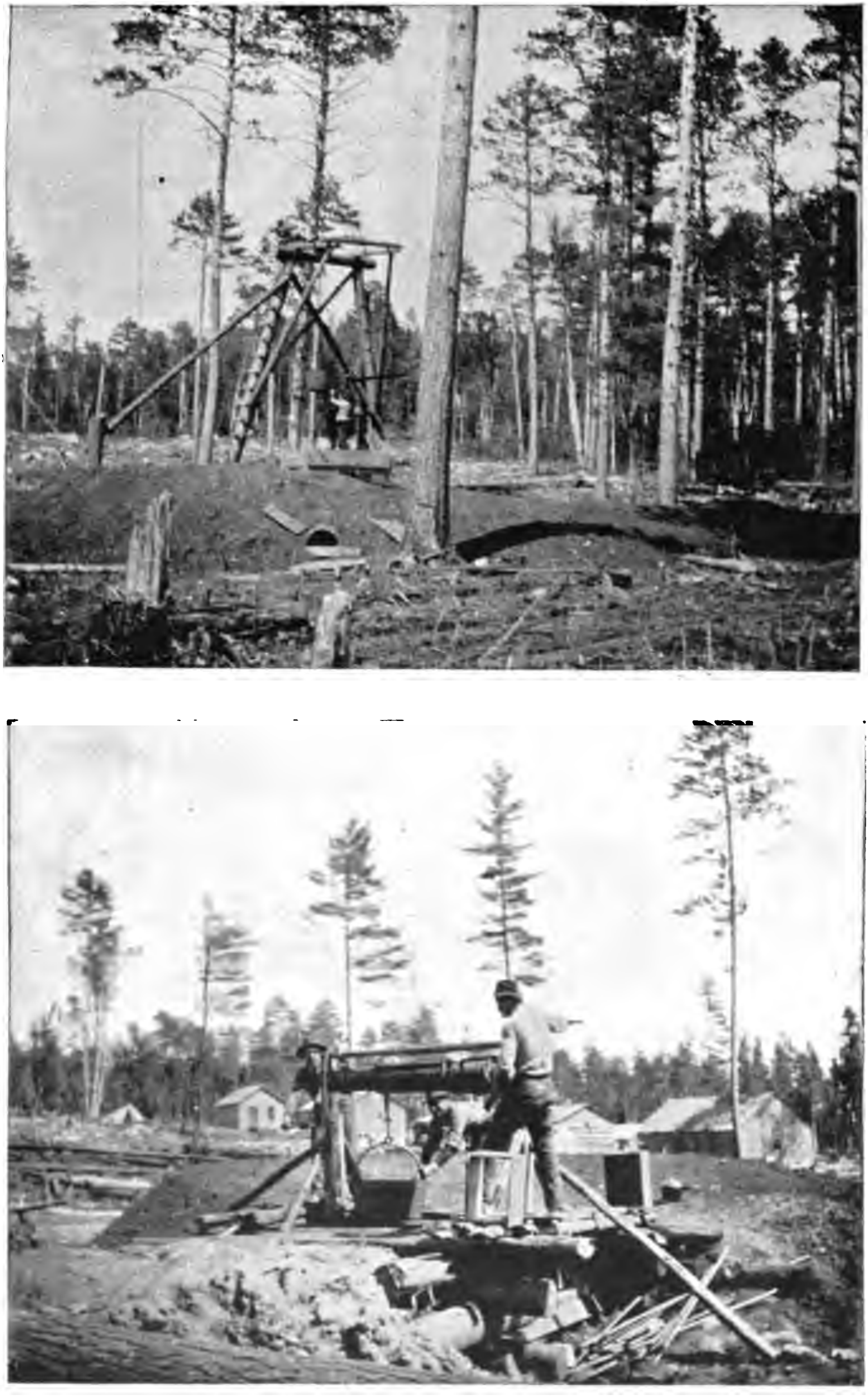
All these facts indicate that the price of bessemer ore will tend to be lower rather than higher, and Mesabi mine owners may well be congratulated that to the excellent quality of their ore is added the combination of great abundance advantageously situated for very cheap mining.

## METHOD OF PROSPECTING.

There is nothing particularly novel or original in the manner in which prospecting is conducted on the Mesabi. An illustration in Agricola's De Re Metallica of a test pit in the sixteenth century shows a windlass operated by a crank at each end almost identical with those employed here three hundred years later. The ancients used two buckets to save time and labor in hoisting. Fig. 7.

The pits are rectangular and vary greatly in diameter. They are seldom timbered below the top of the ore unless very deep and wet. During the winter time pits are sunk in favorable situations to the depth of more than one hundred feet with pick and shovel unaided by a single drill hole or blast of powder. In the spring, however, surface water bothers greatly and pumps are needed. At times there are strata of hard ore or a capping of rock to be penetrated. Drilling and blasting are then resorted to.

The ore is hoisted out in buckets and piled up around the mouth of the pit in a circular dump or stock pile. Plate No. V. is an illustration of a windlass and dump. When the pit is more than one hundred feet in depth the operation of hoisting by hand is a very slow one, and a "bent" is sometimes arranged for hoisting by horse power and dumping into a tram car. This method was first employed on the Mesabi at the Biwabik in the northeast drift at pit No. 15. On Plate No. V. is also an illustration of the bent.



TEST-PITTING AT THE BIWABIK MINE.

CAMPS AT THE WYOMING MINE.

If the ore deposit lies in a rock-rimmed basin there is considerable water in the ore. If it lies on a hillside and is of considerable extent the water filters down through the ore to the basal quartzyte and the upper part of the ore body is quite dry even in very wet seasons. From this it follows that the presence of water in an ore pit is simply an indication that it cannot get away, while its absence is a sign that it can escape, probably by filtering down in the ore, which is therefore concluded to be of considerable amount. The significance of the various rocks and their usual appearance have already been discussed.

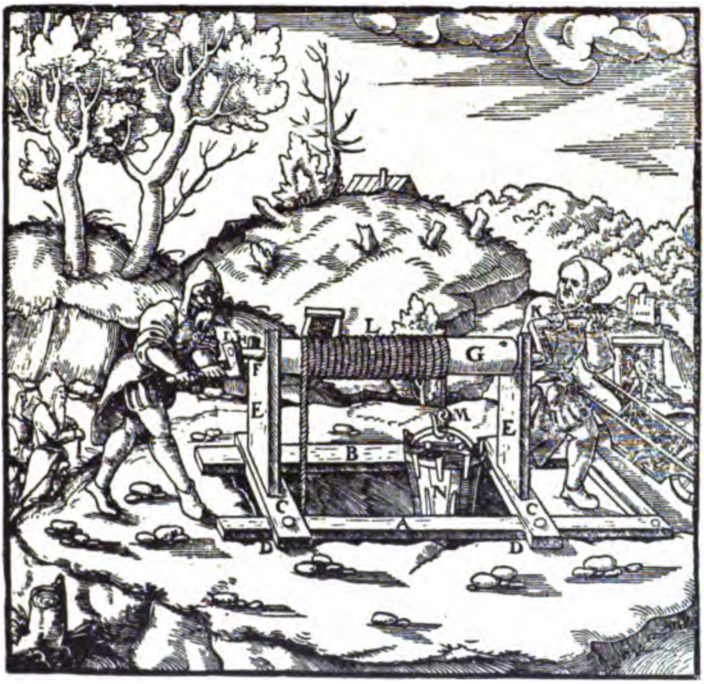


Fig. 7. Test-pitting in the sixteenth century.

## Mines Now Opened Up.

### *Biwabik.*

After the discovery of the Mountain Iron mine in 1890, described in the first portion of this article, no further discoveries of importance were made until about a year later, when an explorer named John McCaskill saw traces of soft ore in the roots of an over-turned tree in section three, T. 58–16. This led to the discovery of the Biwabik, Cincinnati, Canton, Hale and Kanawha mines. Credit for the actual discovery of the ore deposit on the Biwabik must be given to Capt. J. A. Nichols. He directed the work which succeeded in making this discovery in August, 1891. Capt. J. G. Cohoe was put in charge of the work here and sunk fifteen test pits during the winter of 1891–'92. It would be somewhat peculiar if the first and second mines to be discovered should turn out to be the best two mines on the range.

In the last part of April the Biwabik Mountain Iron Company leased three forties in sections two and three, T. 58–16, to Mr. P. L. Kimberley, of Sharon, Pa. The lessees are required to mine at least 300,000 tons per annum and to pay a royalty of 50 cents per ton. This deal was the result of an examination of the early developments on the range made by Mr. J. T. Jones, the superintendent of the Hamilton Ore Company, of Iron Mountain, Mich. Work of exploration was continued in a systematic manner and soon became the model for such work on the range. The test pits were rapidly increased in depth and number, and the result showed the wisdom and foresight of Messrs. Jones and Kimberley in the selection of this property out of all those so far discovered on the range. Records of some of their test pits may be seen on page 138. By the time these test-pits were completed it was evident to the unprejudiced observer that here is the greatest deposit of ore known on the range if not in the whole Lake Superior district. Millions of tons of soft hematite, averaging 63 per cent. iron and .045 phosphorus, are here found within one hundred feet of the surface of the ground. It is safe to say that this mine under its present management will eclipse all former records for cost of mining and number of tons produced in a given length of time. There may yet be larger deposits found on the Mesabi, but so far the Biwabik is chief. The Mountain Iron may prove to be its equal, and at present is a good second, but the number of cubic feet of ore reasonably to be estimated as "in sight" at the Biwabik exceeds that of any two other mines yet opened up.

### *Cincinnati.*

Adjoining the Biwabik on the east is the Cincinnati. This is also a fine property. It does not seem to get the credit it deserves among those familiar with the range, perhaps because it happens to suffer somewhat in comparison with the Biwabik adjoining, which is a larger property and has been more extensively developed. For several months no property on the range could make a better showing as to quantity and quality of ore than the Cincinnati. Subsequent development revealed others equally as good, but that was only to be expected. Later development on this property also showed the ore to be more extensive than the owners themselves believed it originally.

This mine is leased to the Standard Ore Company, who have agreed to mine at least 150,000 tons each year at a royalty of 55 cents per ton.

The development of this property was largely under the charge of Capt. Edward Florada and Capt. Carlin.

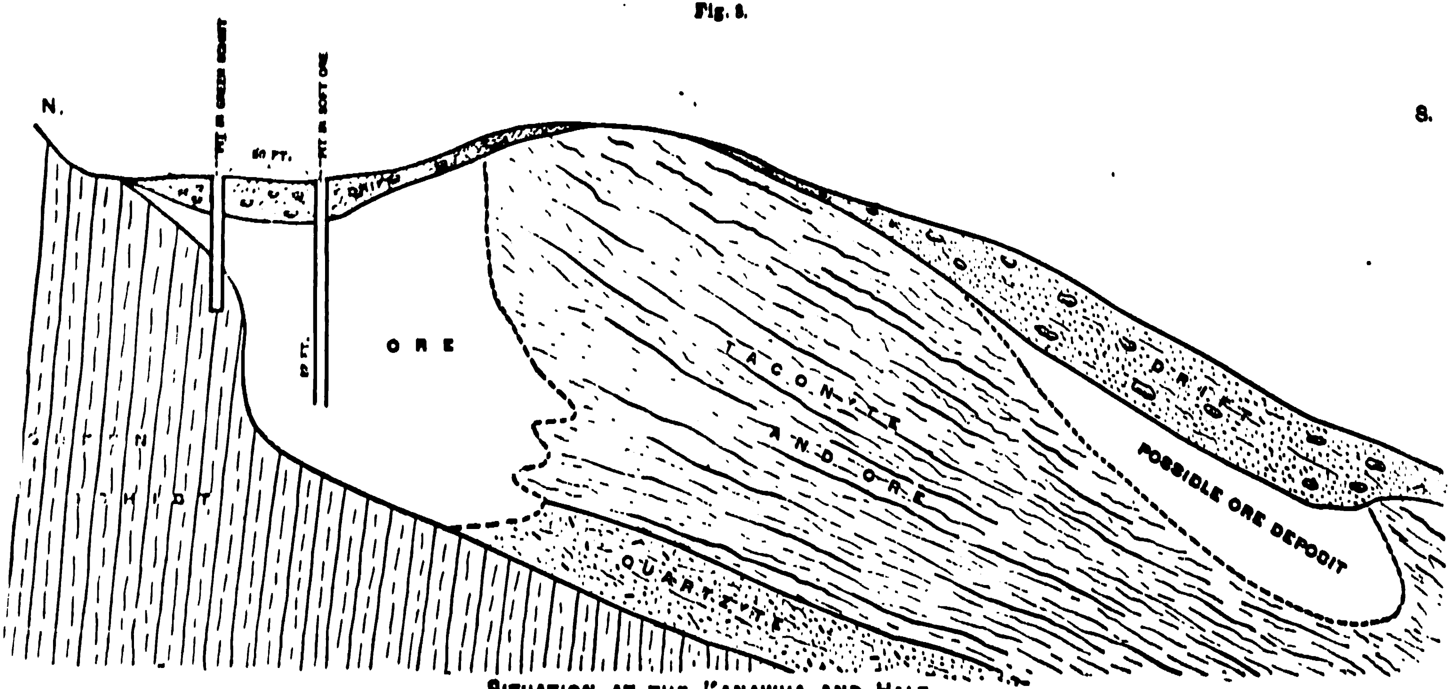
### *Canton.*

This property, owned by the Minnesota Exploration Company, lies on the west side of the Biwabik. The ore here was discovered by Mr. Edgar Brown. Much of it is non-bessemer gœthite. It is probable that there is better ore to be found here at a greater depth. Work is now being vigorously prosecuted under the direction of President D. H. Bacon of the Minnesota Iron Company.

### *Kanawha and Hale.*

The Kanawha Iron Company did considerable exploration work in the S. E. ¼ N. W. ¼ section 1, T. 58–16, in April, 1892, and found a considerable depth of ore in a series of test pits located east and west along the north side of the forty. The width of the deposit is not yet proven to be great here, the ore appearing to lie in a rather narrow gorge. The peculiar relation of the ore deposit at this place to the green schist or "greenstone" is shown by Fig. 8. Pit No. 1 went through the ore at the depth of thirty-eight feet into an unaltered portion of the taconyte. On this property and the Hale, which lies just to the east, the fact is plainly shown that the drainage slope considered necessary to facilitate the replacement process does not always consist of the rocks of the Taconic formation above the ore deposit itself. The flow of waters which has accomplished the replacement and concentration may have come from a ridge of Keewatin green schist or Archæan granite. At this place there are two pits fifty feet apart, one in fifty-five feet of ore and the other in green schist. The schist is the same as that seen elsewhere on the range and lies unconformably beneath the Taconic rocks. It dips here N. 85°, while the dip of the ore is S. 10°. The ore occupies a gorge at the contact line between the two formations. The same deposit in the same relative position extends eastward across the Hale forty. The bare ridges of green schist rise much higher northward, and drainage is off the schist ridges into the valley in which the ore is found. The fact that the ore on these two properties is largely a non-bessemer

Fig. 8.



SITUATION AT THE KANAWHA AND HALE.

Am. Bank Note Co. N.Y.

gœthite is an indication that the replacement is not so perfect in this situation as when the entire slope is composed of the Taconic iron formation.

### *Missabe Mountain.*

A pit located with very good judgment by Capt. J. G. Cohoe, one of the earliest and best explorers on the range, encountered ore on this property, N. E. ¼ section 8, T. 58-17, in the first pit sunk, at the depth of thirteen feet. This was in the last of March, 1892. The first ore discovered in this township was on this property. Other pits on the same land revealed a large deposit of ore of good quality, and in about four months a lease was made to H. W. Oliver, of Pittsburgh, on a guaranteed output of 400,000 tons annually, at the high royalty of 65 cents per ton. The income of this company is thus assured to be more than a quarter of a million of dollars from this property alone. An advance royalty of $75,000 was paid by Mr. Oliver. So quickly are iron mines developed and turned into cash on the Mesabi.

### *Ohio.*

The Ohio Iron Company moved their workmen to the corner of their property nearest the first pit on the Missabe Mountain in April, and were rewarded by finding soft blue hematite of excellent quality in several pits. Early in June this property was leased to James Sheridan, of Duluth, and others, who agreed to pay $97,500 a year in royalties at the rate of 65 cents per ton.

### *Lake Superior.*

In February or March ore was found in the northeast quarter of section 22, T. 58-20, on the land of the Lake Superior Iron Company. This was the fourth township in which ore had been found and its discovery added greatly to the already intense excitement in Duluth. The statement was often made that the whole country was full of iron ore and that a test-pit could hardly fail to find it. Some were of the opinion that iron ore would be so abundant as to be worthless, and that the mines were equally so. It is needless to say that this opinion was held by those who were ignorant of the immense consumption of iron in this country. It is also superfluous to add that this idea was exaggerated beyond all bounds.

Several test pits found ore on the property of this company, both at the first location and at another farther west. As yet no sublease has been made by this corporation, and their intention may be to do their own mining.

At the Mountain Iron mine the quartzyte is underlain by granite as it is also at the Lake Superior.

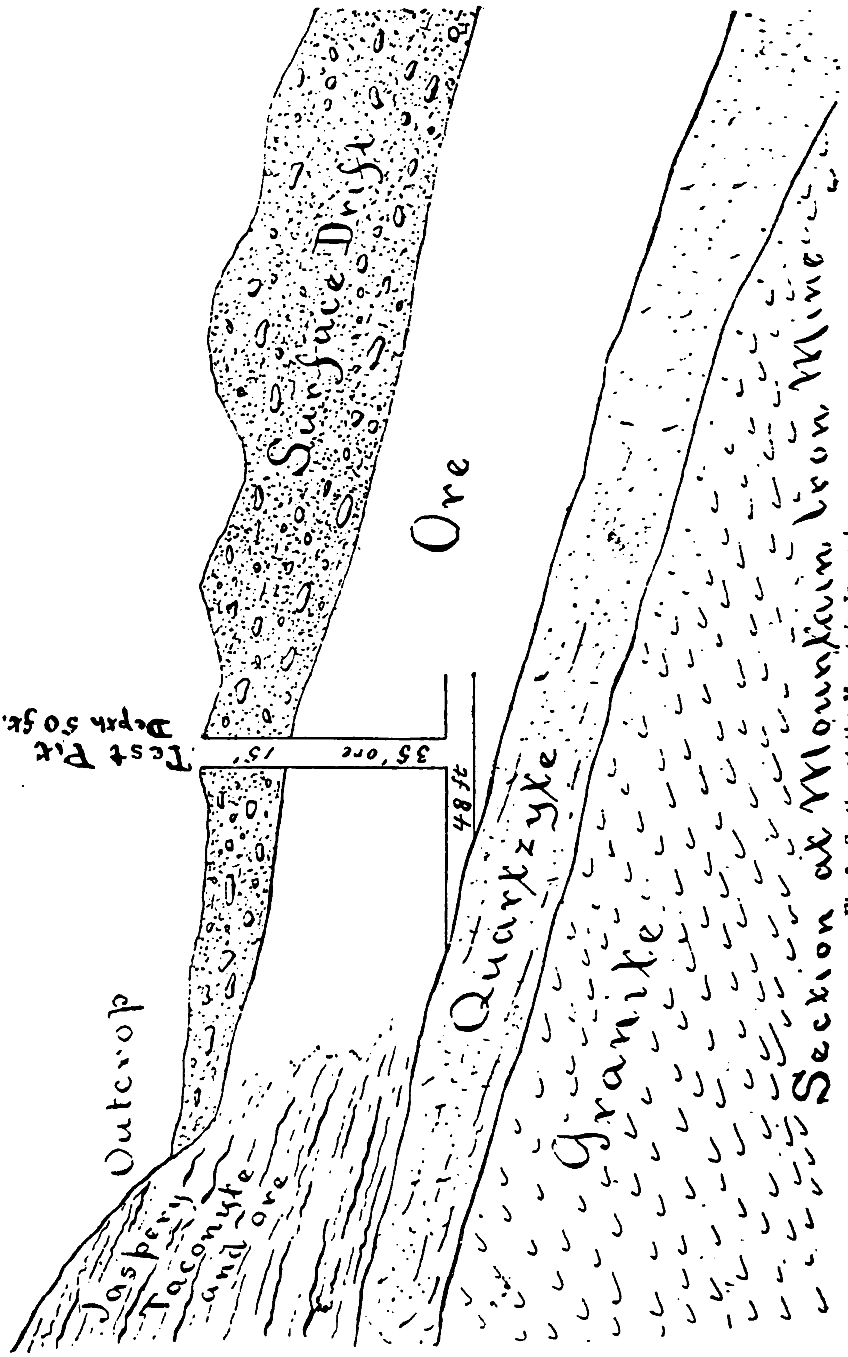


Fig. 9. Section at the Mountain Iron mine.

## *New England.*

In May a fine body of ore was discovered by John Owens on the property of the New England Iron Company, N. W. ¼ N. W. ¼ section 9, T. 58–17. Later developments have shown the existence of nearly forty acres of ore, and most of it is the peculiar soft blue ore, which is the best on the range. In August this property was subleased to Capt. N. D. Moore and others at a royalty of 55 cents per ton and an advance royalty of $50,000. This company controls other lands favorably situated for the existence of merchantable ore bodies.

## *Virginia.*

The Virginia Iron Company also found ore in the N. E. ¼ S. E. ¼ section 8, T. 58–17, during the month of May. This property was leased in August for a valuable consideration. A number of test pits indicate that there is ore over a large area on the land of this company. Like the New England, Wyoming, Lone Jack, Kanawha and others, it belongs chiefly to A. E. Humphreys & Co., who were fortunate in their selection of lands and who spared no expense in the rapid and thorough exploration of them. The phenomenally quick development of the new range is due perhaps more largely to their efforts than to those of any other single firm or individual. Their confidence in the district and their earnest efforts to develop it deserve abundant thanks and reward.

## *"Paddack's."*

Ore was found on the S. W. ¼ N. E. ¼ section 3, T. 58–18, east of the Mountain Iron mine, in May. This was the second property in this township to show a good body of ore. The glacial drift here exceeds fifty feet in depth and water is troublesome, but the body of merchantable ore appears to be of considerable extent.

## *Lone Jack, Wyoming, Security, Great Western and Rouchleau.*

Along in May ore was found on the above properties, all situated in T. 58–17. There is a large bend in the green schist ridge in this township and the largest group of mines on the range is situated on the flanks of this loop or bend. As will be seen from the map these mines follow the curving line of the greenstone ridge, and occur on its flanks, irrespective of the direction it may happen to assume. No detailed description of each property and its develment will be given here, for the work is not sufficiently advanced to warrant it and the main features are similar to those already described on other properties.

There is, however, one peculiar occurrence on the Lone Jack and Missabe Mountain to which reference has already been made.

There appears to be a pre-glacial gorge formerly excavated by some stream flowing in a westerly direction down from the green schist ridge across the Lone Jack and Missabe Mountain into the valley in the southwest part of the township. This gorge was in some way filled with gravel, at the present time composed principally of round, water-worn fragments of hard ore. The drift mantle was subsequently spread over the top of the filled gorge and the ore on both sides of it. At the bottom of this gravel-filled gorge is a stratified layer of light colored kaolinic material which varies in thickness from a few inches to twelve feet. Beneath this stratum of kaolin is soft blue hematite similar to that found by test pits north and south of the supposed gorge on both the Lone Jack and Missabe Mountain. The depth of this ore gravel in the gorge is more than sixty feet. The test-pits sunk on both sides of it encounter ore at the depth of from eight to fifteen feet as the thickness of the drift varies. The so-called ore-gravel is mostly hard, dark colored hematite and is cemented by a soft ferruginous paste containing more or less of the kaolinic matter. It is not certain that this gravel was ore when it was deposited in its present position, but it does appear likely that it is not a constituent part of the Taconic strata. The fine deposit of kaolin which separates it from the blue ore below and on the sides was perhaps derived from the detritus of the feldspathic green schist, although it is similar to material found elsewhere at the base or lower edge of deposits of ore, and may thus be a product of chemical alteration *in situ*.

### *McKinley.*

In December, 1891, ore was found on the McKinley, N. W. ¼ S. E. ¼ section 8, T. 58–16. During January work progressed rapidly under the direction of Mr. D. McKinley. Three pits were sunk in good soft blue hematite. Having proven the existence of a good mine here work ceased, until railroad facilities could be obtained, before the full extent of the deposit was revealed. The property is a large one and there is abundant opportunity for a very fine deposit of ore.

During the winter of 1891–'92 work was vigorously prosecuted on all these properties, and the discovery of such a large amount of ore produced quite an excitement in Duluth and among northwestern iron miners, in the months of January, February and March, 1892. Many new companies with a very large capital stock were organized, and the work of searching for iron deposits was begun in dozens of camps in the dead of win [illegible] erected and tons of supplies were taken on runners to the various locations west of Mesaba station on the Duluth and Iron Range railroad. The organization of these companies was a matter of speculation. The lands were held under State or private lease at a royalty of 25 or 30 cents per ton, or in fee, and were selected without any knowledge of the region or the properties or the possibility of the discovery of ore thereon. It was to be expected that many companies would be disappointed in the search for ore and that the expense of operating would soon drain the exchequers of others. This was in fact the case, but it must be admitted that the number of successful ones was surprisingly large.

### *Other discoveries of ore.*

There are authentic reports of the discovery of merchantable ore in townships 58–20, 58–21 and 57–22, on the lands of the Washington, Mesabi Chief and Lake Superior Iron companies, as well as on land under lease to J. M. Longyear. These have not been visited recently by the writer. Neither has the Diamond mine in 56–24. This mine has been operated for several years under the superintendence of Mr. E. W. Griffin, of Minneapolis. The results were not at first satisfactory, and considerable trouble was experienced with water. It is reported that the work is at present being conducted in a body of good soft ore. The Gunflint Lake Iron Company, under the direction of Mr. John Paulson, is preparing to mine the magnetic ore on the eastern end of the Mesabi range in township 64–5. The Port Arthur, Duluth and Western railroad is in operation to a point near these deposits.

LIST OF SUB-LEASES ALREADY MADE.

| Mine. | Royalty. | Advance royalty. | Minimum output, tons. |
|---|---|---|---|
| Cincinnati. [To Standard Ore Co.] ... | $.55 | $25,000 | 150,000 |
| Biwabik. [To P. L. Kimberley.]..... | .50 | ...... | 300,000 |
| Biwabik. [To Berringer et al.]....... | .50 | ...... | *100,000 |
| Virginia. [To Weimer et al.] ......... | .50 | 25,000 | 50,000 |
| Wyoming. [To A. J. Decker.]....... | .30 | 40,000 | 25,000 |
| Wyoming. [To. J. T. Jones.]........ | .50 | ...... | 25,000 |
| Wyoming. [To Parkersburg Iron Co.] | .50 | 30,000 | 50,000 |
| New England. [To N. D. Moore.].... | .55 | 50,000 | 150,000 |
| New England. [To J. B. Weimer.]... | .50 | 25,000 | 50,000 |
| Lone Jack. [To Moore & Foley.]..... | .65 | ...... | 50,000 |
| Missabe Mountain. [To H. W. Oliver] | .65 | 75,000 | 400,000 |
| Ohio. [To Jas. Sheridan et al.]...... | .60 | ...... | 150,000 |
| Hale. [To F.A.Bates and H.P.Barbour] | .50 & .40 | ..... | 50,000 |
| | | | 1,550,000 |

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*50,000 tons each alternate year.

# LIST OF MINING COMPANIES INCORPORATED IN MINNESOTA DECEMBER 1, 1890, TO SEPTEMBER 1, 1892.*

[The name of the company is followed by the place of its principal office, the amount of capital stock, number of shares, date of incorporation and names of incorporators.]

**Alaska Mexican Gold Mining Company;** St. Paul; $1,000,000; 200,000 shares; Nov. 17, 1891. S. M. Magoffin, F. S. Kirkpatrick, J. T. Rogers.

**Allegheny Iron Mining and Milling Company;** Duluth; $1,500,000; 150,000 shares; May 11, 1892. C. C. Merritt, W. O. Tillotson, P. Hamil, Grant Wyatt, D. W. Evans.

**American Mining Company;** Minneapolis; $3,000,000; 30,000 shares; March 1, 1892. D. M. Clough, J. B. Sutphin, R. Jamison, F. G. James.

**Anderson Iron Company;** Duluth; $1,000,000; 40,000 shares; July 16, 1891. A. R. Macfarlane, W. C. Sherwood, J. T. Hale.

**Athens Iron Company;** Duluth; $3,000,000; 30,000 shares; March 3, 1892. L. Merritt, A. Merritt, R. H. Palmer.

**Atikokan Iron Company;** Duluth; $250,000; 2,500 shares; Jan. 19, 1892. S. Meniece, A. Snyder, W. Getty, E. J. McLaughlin, M. McManus, J. I. Gilbert, W. McRae, A. P. Cook.

**Aurora Iron Company;** Duluth; $3,000,000; 30,000 shares; April 8, 1892. J. McKinley, A. E. Humphreys, P. S. Bemis, J. Billings, G. N. Bissell.

**Bessemer Iron Development and Mining Company;** Duluth; $100,000; 1,000 shares; Aug. 23, 1892.

**Bessemer Iron Company;** Duluth; $3,000,000; 120,000 shares; Feb. 27, 1892. L. J. Hopkins, G. H. Claypool, H. S. Mahon, C. J. Kershaw, A. E. McCordic, W. B. Silvey, W. G. Crosby, E. C. Jones.

**Biwabik Mountain Iron Company;** Duluth; $2,000,000; Oct. 9, 1890; $3,000,000; 30,000 shares; Oct. 17, 1891. L. Merritt, E. H. Hall, J. J. Wheeler.

**Boston Iron Company;** Duluth; $2,000,000; 20,000 shares; March 1, 1892. J. McKinley, G. W. Buck, G. F. Piper, J. T. Hale.

**Boston Iron Company;** Duluth; $3,000,000; June 16, 1892. Changed to McCaskill Mining Company.

**Bradley Iron Company;** Duluth; $2,000,000; 20,000 shares; March 1, 1892. H. C. Hanford, G. F. Piper, E. L. Bradley.

**Buckeye Iron Company;** St. Paul; $3,000,000; 30,000 shares; March 4, 1892. F. Barrett, E. D. Sawyer, J. H. James, W. W. Braden, J. H. Baker.

**Buffalo Land and Exploration Company;** Duluth; $125,000; 125,000 shares; July 27, 1892. W. E. Richardson, C. Adams, J. T. Hale, H. W. Coffin, O. H. Hewit, D. G. Cash, J. D. Stryker.

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* For a list of all the companies previously incorporated in Minnesota for the purpose of mining see Bulletin No. 6, "The Iron Ores of Minnesota," p. 335.

**Camden Iron Company;** Duluth; $1,000,000; March 25, 1892; $1,200,000; 12,000 shares; April 5, 1892. J. G. Williams, J. B. Lovell, H. G. Ingersoll, A. J. Decker.

**Carnegie Mining Company, The;** Duluth; $1,000,000; 10,000 shares; April 4, 1892. S. P. Davidge, E. Zohrlaut, R. F. Fitzgerald, T. E. McGarr, J. R. Bell.

**Central American Mining and Improvement Company;** St. Paul; $100,000; 20,000 shares; Jan. 4, 1892. W. M. Davis, P. Fletcher, S. M. Magoffin.

**Central Vermilion Iron Company;** St. Paul; $800,000; 80,000 shares; March 22, 1892. E. A Hendrickson, A. Scheffer, E. J. Hodgson, C. W. Cox, L. E. Judson, Jr.

**Champion Iron Company;** Duluth; $3,000,000; 30,000 shares; March 1, 1892. W. McRae, J. I. Gilbert, C. F. Howe.

**Charleston Iron Company;** Duluth; $2,000,000; 20,000 shares; Feb. 11, 1892. J. McKinley, F. Cox, A. E. Humphreys.

**Chicago Iron Company;** Duluth; $5,000,000; 50,000 shares; Feb. 15, 1892. A. E. Humphreys, E. C. Gridley, J. McKinley, J. T. Hale.

**Cincinnati Iron Company;** Duluth; $3,000,000; 120,000 shares; Nov. 24, 1891. L. Prichard, F. Woodman, A. E. Humphreys, J. McKinley, J. T. Hale.

**Clark Iron Company;** Duluth; $3,000,000; 30,000 shares; March 7 1892. M. J. Clark, F. Jewell, M. W. Bates, G. F. Piper, A. B. Upton, C. F. McComb.

**Cleveland Iron Company;** Duluth; $200,000; 2,000 shares; Jan. 28, 1892. J. McKinley, G. J. Atkins, M. O. Brooks.

**Columbia Iron Company;** Duluth; $3,000,000; 30,000 shares; March 14, 1892. J. McKinley, D. McKinley, G. S. Ostrum, J. E. Lobdell, S. O. Brooks, T. E. Yerxa, E. B. Swygart, G. M. Bissell, A. C. Clauson.

**Columbus Iron Company;** St. Paul; $2,000,000; 20,000 shares; March 23, 1892. F. Barrett, W. W. Braden, M. Clark, J. McCarthy, A. S. Bates, M. O. Brooks.

**Comstock Iron Mining Company;** Duluth; $5,000,000; 50,000 shares; March 11, 1892. G. T. Porter, F. W. Merritt, G. A. Elder, A. D. Thomson, M. Simpson, W. M. Holbrook.

**Consolidated Missabe Iron Company;** Duluth; $3,000,000; 30,000 shares; March 14, 1892. G. M. Nelson, L. Merritt, R. Jamison, A. Erwin. J. Mather, K. D. Chase.

**Cosmopolitan Iron Company;** Duluth; $4,000,000; 40,000 shares; March 11, 1892. J. McKinley, F. W. Winship, A. E. Humphreys.

**Dayton Iron Mining Company;** Duluth; $1,000,000; 10,000 shares; Feb. 29. 1892. J. C. Semple, J. W. Earl, W. P. Strickland, J. F. Landry, N. A. Gearhart, C. A. Long, W. A. Barr, H. P. Haskell, G. F. Copeland.

**Detroit Iron Company;** Duluth; $3,000,000; 120,000 shares; Feb. 18, 1892. J. T. Hale, F. E. Kennedy, J. M. Root.

**Diamond Iron Mining Company, The;** Minneapolis; $100,000; 1,000 shares; Aug. 20, 1892. G. F. Warner, A. Richardson, H. H. Smith.

**Donald Grant Mining Company;** Duluth; $50,000; 500 shares; March 14, 1892.

**Duluth Iron Mining Company;** Duluth; $200,000; 2,000 shares; March 3, 1892. F. Cox, S. W. Eckman, A Howell.

**Duluth Mining Investment Company;** Duluth; $50,000; 500 shares; March 16, 1892.

**Duluth Ore Company;** Duluth; $100,000; 4,000 shares; May 16, 1892. J. R. Berringer, A. H. Stevens, J. B. Weimer.

**Elk Iron Mining Company, The;** St. Paul; $3,000,000; 30,000 shares; April 13, 1892. C. R. Groff, D. D. Merrill, Jr., W. B. Richards, J. L. Stack.

**Gowan Mining Company;** Minneapolis; $500,000; 100,000 shares; May 26, 1892. A. H Linton, R. B. Langdon, R. B. Conkey, C. S. Langdon, J. A. Gowan.

**Great Northern Mining Company;** Duluth; $2,000,000; 20,000 shares; Jan. 2, 1892; $3,500,000; 35,000 shares; April 2, 1892. G. L. Robbins, E. T. Merritt, J. T. Culbertson, N. B. Merritt, E. R. Brace, T. A. Merritt, R. W. Allnutt, F. W. Merritt, H. A. Wing.

**Great Western Mining Company;** Duluth; $6,000,000; 60,000 shares; March 5, 1892. A. Merritt. L. Merritt, G. L. Robbins, J. Culbertson, E. T. Merritt, F. W. Merritt, N. B. Merritt, C. C. Merritt, D. B. Searle, C. A. Gilman, M. Simpson.

**Guaranty Silver Mining Company;** Minneapolis; $500,000; 500,000 shares; June 5, 1891. A. C. Dunn, J. G. Ricke, A. D. Westby, C. D. White, E. Robinson.

**Gunflint Lake Iron Company;** Duluth; $100,000; 1,000 shares; Mar. 24, 1892. J. Paulson, K. Kortgaard, O. D. Kinney.

**Hale Iron Company;** Duluth; $3,000,000; 30,000 shares; Mar. 2, 1892. J. T. Hale, E. C. Gridley, J. Norton.

**Henderson Mountain Mining and Milling Company, The;** St. Paul; $100,000; 1,000 shares; July 27, 1892. W. E Nichols, H. J. Chittenden, L. Blanden, W. A. Jones.

**Henrietta Iron Company, The;** Minneapolis; $50,000; 500 shares; April 27, 1892. G. F. Moulton, O. J. Nevitt, J. Paulson, G. A. Morse, W. H. Cooper.

**Hidden Treasure Silver Mining Company;** Minneapolis; $100,000; 100,000 shares; Dec. 28, 1891. D. McKenzie, N. Campbell, L. Kimball, F. W. Nevens, W. R. Steadman.

**Horton Mining Company;** Duluth; $500,000; 50,000 shares; Jan. 28, 1892; $1,000,000; 100,000 shares; Feb. 20, 1892. G. W. Horton, S. G. Wightman, R. H. Harris, W. E. Worden, S. S. Smith, H. B. Moore, W. D. Edson, R. P. Edson.

**Imperial Mountain Iron Mining Company, The;** St. Paul; $1,000,000; 10,000 shares; April 11, 1891. J. P. Heatwole, J. Roach, A. B. Kelly, S. Finkelson, L. D. Baird, W. B. Joyce, J. J. Furlong.

**Iron Belt Mining Company;** Duluth; $1,000,000; 40,000 shares; Mar. 1, 1892. A. J. Trimble, F. Hibbing, L. E. Judson.

**Iron Cliff Mining Company;** Duluth; $3,000,000; 30,000 shares; March 5, 1892. H. Keller, J. C. Flynn, J. Kraker, S. S. Titus, J. R. Howes, W. N. Holbrook, M. Johnson, A. B. Plough, T. G. Alvord, N. C. Thrall, J. B. Sutphin, *et al.*

**Kakina Iron Company;** Duluth; $1,000,000; 40,000 shares; Dec. 4, 1891. W. H. Fisher, D. Grant, D. H. Merritt.

**Kaministique Iron Company;** Minneapolis; $100,000; 10,000 shares; Dec. 3, 1891. S. H. Hall, H. S. Smith, G. A. Castle, R. D. Arundell, C. L. Stacy, A. M. Hillman, E. W. Ginter.

**Kanawha Iron Company;** Duluth; $2,000,000; 20,000 shares; Feb. 15, 1892. A. E. Humphreys, J. T. Hale, G. E. Milligan.

**Kentucky Iron Company;** Duluth; $1,000,000; 10,000 shares; March 8, 1892. F. W. De Vey, W. H. Smallwood.

**Keystone Iron Company**; Duluth; $3,000,000; 30,000 shares; March 4, 1892. C. Markell, A. C. Otis, F. G. Stevens, W. E. Richardson, H. W. Pearson, E. R. Brace, F. B. Lazier, J. T. Hale, C. L. Codding.

**Lackawanna Iron Company**; Duluth; $3,000,000; 30,000 shares; Mar. 3, 1892. F. L. De Forest, W. G. Park, M. J. Davis, E. F. Clark, J. A. Taylor.

**Lake Superior Iron Company**; Duluth; $5,000,000; 200,000 shares; March 17, 1892. A. J. Trimble, W. D. Vernam, W. H. Buffum, F. Hibbing, W. Munro.

**Licking Mining Company**; St. Paul; $3,000,000; 30,000 shares; April 22, 1892. F. Barrett, W. W. Braden, A. W. Thurman, W. V. Marquis, J. H. Newton.

**Lincoln Iron Company**; Duluth; $3,000,000; 30,000 shares; March 19, 1892. H. H. Myers, F. Cox, A. Howell.

**Little Mesabi Iron Company**; Minneapolis; $3,000,000; 30,000 shares; March 15, 1892. R. W. Cavenaugh, E. S. Bean, G. H. Dodge, E. F. Dodge, A. C. Paul.

**Lone Jack Iron Company**; Duluth; $500,000; 5,000 shares; Aug. 26, 1892. A. E. Humphreys, G. E. Milligan, A. Howell.

**Lucky Hit Mining and Milling Company**; Minneapolis; $250,000; 250,000 shares; March 11, 1891. S. Parker, W. F. Albee, J. L. Parker.

**Mallmann Iron Mining Company**; Duluth; $1,000,000; 100,000 shares; March 5, 1892. A. H. Viele, A. J. Trimble, F. L. Cowen. Increased capital stock.

**McCaskill Mining Company**; Duluth; $3,000,000; 30,000 shares; June 16, 1892. Changed from **Boston Iron Company.**

**McKinley Iron Company**; Duluth; $5,000,000; 50,000 shares; May 25, 1892. W. McKinley, J. Charnley, J. McKinley, G. N. Bissell, D. McKinley, J. Billings.

**Merritt Nickel Mining Company**; Duluth; $2,000,000; 20,000 shares; May 24, 1892. F. W. Merritt, G. W. Mann, W. H. Prescott.

**Mesabi Chief Iron Company**; Duluth; $3,000,000; 30,000 shares; March 1, 1892. W. B. Gardner, J. C. Mishler, S. G. Wightman, R. F. Willcuts, C. D. Smith.

**Mesabi Iron Range Mining Company**; St. Paul; $4,000,000; 40,000 shares; March 27, 1892. S. McClure, S. Matthews, J. J. Howe.

**Minawa Iron Company**; Duluth; $50,000; 500 shares; Aug. 20, 1891. W. H. Fisher, D. H. Merritt, J. H. Upham, L. Merritt, W. A. Barr.

**Minneapolis and Webb City Mining Company**; Minneapolis; $100,000; 10,000 shares; Aug. 18, 1891. F. A. Fisher, W. H. Mitchell, W. M. Barrows, D. G. Michell, S. P. Channell, J. A. Bowman, S. A. Reed, J. B. Starkey, J. H. Clark.

**Minneapolis Iron Company**; Minneapolis; $3,000,000; 30,000 shares; Feb. 23, 1892. E. M. Mabie, A. R. McGill, G. L. Becker, C. N. Smith, W. S. Milnor, J. J. Ankeny.

**Minneapolis Mineral Land Company**; Minneapolis; $50,000; June 19, 1891. J. I. Best, J. S. Lane, C. E. Brewster, L. M. Lane, J. F. Calhoun, M. McKinney, W. Miller, E. J. Edwards, E. I. Ewing, O. Jones, O. F. Schmid.

**Minneapolis Mining and Milling Company**; Minneapolis; $500,000; 500,000 shares; Dec. 26, 1891. J. Pye, S. Parker, W. Hartley, W. F. Albee, J. L. Parker.

**Minnehaha Mining and Milling Company**; Minneapolis; $500,000; 500,000 shares; April 26, 1892. G. Danforth, L. P. Crevier, F. H. Wendell, K. E. Brewster, D. F. Strobeck.

**Minosin Iron Company;** Duluth; $50,000; 500 shares; Aug. 20, 1891. W. H. Fisher, J. H. Upham, D. H. Merritt, L. Merritt, W. A. Barr.

**Missabe Central Land and Exploration Company;** Duluth; $100,000; 10,000 shares; Jan. 2, 1892. A. Merritt, R. H. Palmer, J. Helmer.

**Missabe and Northern Townsite Company;** Duluth; $50,000; 500 shares; March 17, 1892. L. Merritt, R. H. Palmer, N. B. Merritt, A. Merritt.

**Missabe Mountain Iron Company;** Duluth; $3,000,000; 30,000 shares; Feb. 4, 1892. L. Merritt, J. E. Merritt, K. D. Chase.

**Missabe Monarch Iron Company;** Duluth; $3,000,000; 30,000 shares; March 12, 1892. L. Merritt, R. H. L. Jewett, W. P. Jewett.

**Missouri Iron Company;** Duluth; $50,000; 5,000 shares; Aug. 4, 1892. L. J. Taussig, A. W. Taussig, T. Bloomfield.

**Myrna Iron Mining Company;** Duluth; $200,000; 100,000 shares; Feb. 14, 1891. T. H. Pressnell, F. Hibbing, R. D. Mallet, A. J. Trimble, F. I. Tedford.

**New Castle Iron Mining Company;** Duluth; $250,000; 25,000 shares; April 4, 1891. A. E. Humphreys, F. I. Tedford, F. Hibbing, T. H. Pressnell, J. A. Boggs.

**New England Iron Company;** Duluth; $3,000,000; 30,000 shares; March 15, 1892. A. E. Humphreys, J. McKinley, A. J. Blethen, L. Swift, Jr., W. H. Lynn.

**New York Iron Company;** Duluth; $3,000,000; 120,000 shares; Mar. 1, 1892. C. C. Merritt, A. R. Merritt, H. W. Coffin, J. T. Hale, E. T. Merritt.

**Nibiwa Iron Company;** Duluth; $50,000; 500 shares; Aug. 20, 1891. W. H. Fisher, J. H. Upham, D. H. Merritt, L. Merritt, W. A. Barr.

**Northern Light Iron Company;** Duluth: $2,000,000; 20,000 shares; March 31, 1892. A. Michaud, A. I. Scarlett, S. Clark, A. M. Cox.

**Ohio Iron Company;** Duluth; $50,000; 2,000 shares; Aug. 12, 1892. J. Sheridan, J. T. Jones, J. B. Weimer.

**Ohio Mining Company;** Duluth; $1,000,000; 100,000 shares; Feb. 1, 1892; $3,000,000; 30,000 shares; April 18, 1892. J. E. Campbell, E. D. Sawyer, W. J. Hilands, C. F. Nester, R. S. Munger, M. R. Baldwin, T. H. Pressnell, J. K. Persons, F. Barrett, S. R. Ainslie.

**Oneota Iron Mining Company;** Duluth; $1,500,000; 15,000 shares; March 1, 1892. F. W. Merritt, J. Frazer, G. W. Mann, G. Wyatt, J. M. McLennan, E. F. Clarke.

**Outcrop Iron Mining Company;** St. Paul; $500,000; 5,000 shares; May 10, 1892. C. A. Hutchinson, G. Lill, J. F. Whiting, D. M. Case, F. Barrett.

**Pacific Mining Company, The;** Duluth; $500,000; 5,000 shares; May 6, 1892. A. Erwin, G. N. Baxter, E. H. Hall, G. N. Nelson, R. Jamison.

**Palisade Mining Company;** Minneapolis; $250,000; Oct. 21, 1891. J. F. Calhoun, L. M. Lane, J. S. Lane, M. McKinney, E. J. Edwards.

**Parkersburg Iron Company;** Duluth; $100,000; 1,000 shares; Sept. 5, 1892. J. Billings, P. S. Bemis, F. Cox.

**Pennsylvania Iron and Steel Company;** Duluth; $3,000,000; 30,000 shares; March 5, 1892. Nels Hall, D. W. Evans, S. W. Clark, A. T. Scarlett, N. A. Gearhart, A. C. Pearsons, G. Wyatt.

**Pipe Lake Nickel Mining Company;** Duluth; $500,000; 50,000 shares; June 9, 1891. R. Forbes, G. N. Stevenson, W. H. Trescott, J. T. Watson, M. Douglas.

**Pittsburgh Iron Company;** Duluth; $100,000; 4,000 shares; Dec. 12, 1891. W. McKinley, J. McKinley, A. J. Trimble.

**Poca Iron Company;** Duluth; $50,000; 500 shares; June 9, 1892. F. Cox, A. Howell, S. W. Eckman.

**Portage Red Sandstone Company;** Duluth; $100,000; 1,000 shares; July 7, 1891. J. D. Lloyd, F. B. Chew, J. H. Hellyer, C. W. McFadden, C. T. Le Tourneau.

**Putnam Iron Company;** Duluth; $3,000,000; 30,000 shares; March 2, 1892. J. T. Hale, E. C. Gridley, S. R. Payne, J. P. Morrow, E. G. Chapman, H. S. Stearns, J. Sheridan, C. d'Autremont.

**Republic Iron Company;** Duluth; $3,000,000; 120,000 shares; March 22, 1892. P. M. Graff, F. W. Eaton, J. G. Brown, R. J. Ryan, A. Erwin, G. M. Nelson, R. Jamison.

**Rouchleau Iron Company;** Duluth; $5,000,000; 50,000 shares; Mar. 18, 1892. L. Rouchleau, F. W. Higgins, G. Gilbert, G. F. Piper, C. E. Shannon, G. W. Buck, T. B. Mills.

**Security Iron Company;** Duluth; $3,000,000; 30,000 shares; March 1, 1892. J. T. Hale, E. T. Merritt, G. W. Buck, G. F. Piper, R. H. Palmer.

**Security Land and Exploration Company;** Duluth; $100,000; 10,000 shares; Dec. 30, 1891. G. W. Buck, G. F. Piper, J. T. Hale, N. B. Merritt, R. H. Palmer.

**Shaw Iron Company;** Duluth; $3,000,000; 30,000 shares; Dec. 21, 1891. D. W. Scott, J. E. Davies, A. R. Merritt, N. B. Merritt, R. H. Palmer.

**Sheridan Iron Company;** Duluth; $1,000,000; 100,000 shares; Dec. 8, 1891. C. E. Shannon, W. C. McComber, R. H. Harris, J. H. Harris, C. M. Gray, A. C. Otis, G. R. Laybourn.

**Silver Chief Mining Company, The;** Minneapolis; $500,000; 500,000 shares; Aug. 18, 1892. M. N. Price, B. F. Moore, C. L. Mendel, F. M. Hutchinson, F. L. Favor, F. E. Mix, W. F. Thayer.

**Southern California Smelting and Refining Company, The;** Los Angeles; $500,000; ——— shares; Sept. 5, 1892.

**Standard Ore Company, The;** Duluth; $1,500,000; 60,000 shares; Aug. 5, 1892. H. W. Oliver, F. A. Bates, H. P. Barbour, A. D. Thompson, B. C. Church, C. A. Congdon.

**Steep Rock Mining and Improvement Company;** Duluth; $50,000; 500 shares; May 13, 1892. L. S. Franklin, H. C. Ash, A. E. Walker.

**Stowell Iron Company;** Duluth; $1,000,000; 100,000 shares; Feb. 16, 1891. W. H. H. Stowell, B. E. Baker, G. F. Long, A. C. Jamison, T. H. Pressnell, S. F. Boyce, F. I. Tedford, J. Zimmermann, L. W. Hizar, F. Barrett.

**St. Paul and Duluth Mining Company;** St. Paul; $1,000,000; 100,000 shares; April 23, 1892. S. S. Smith, W. H. Squier, J. C. Southall, W. Ruan, W. P. Curtiss, R. H. Edwards, P. P. McVeigh, Jr.

**Swan Lake Iron Mining Company of Minneapolis;** Minneapolis; $1,000,000; 40,000 shares; April 4, 1892. G. H. Warren, W. G. La Rue, D. Waite.

**Swedish American Iron Company;** Duluth; $2,000,000; 20,000 shares; Feb. 23. 1892. C. A. Smith, O. N. Ostrum, N. O. Werner, J. Peterson, L. M. Erickson, A. Nelson, N. Hall, J. J. Eklund, N. A. Linderberg, J. A. Carlson.

**Towanda Iron Company;** Duluth; $3,000,000; 30,000 shares; March 2, 1892. J. T. Hale, B. T. Hale, J. Sullivan, R. H. Palmer, A. Merritt.

**Twin City Iron Company;** Duluth; $3,000,000; 30,000 shares; March 1, 1892. J. McKinley, A. E. Humphreys, G. E. Milligan.

**Vermilion Iron and Land Company of Duluth**; Duluth; $1,000,000; March 8, 1892. Changed name to **Kentucky Iron Company.**

**Virginia Iron Company**; Duluth; $3,000,000: 30,000 shares; March 1, 1892. J. McKinley, G. F. Piper, A. L. Warner.

**Vulcan Iron Company**; Duluth; $1,000,000; 100,000 shares; Feb. 29, 1892. F. Walker, A. H. Morris, M. A. Morris, C. O. Munns, R. H. Harris.

**Wabigon Iron Company**; Duluth; $50,000; 500 shares; Aug. 20, 1891. W. H. Fisher, D. H. Merritt, J. H. Upham, L. Merritt, W. A. Barr.

**Wahkootah Iron Company**; Duluth; $3,000,000; 30,000 shares; Mar. 14, 1892. L. Merritt, E. H. Hall, R. Jamison, J. Mather.

**Washington Iron Company**; Duluth; $3,000,000; 30,000 shares; Mar. 2, 1892. T. B. Mills, G. F. Piper, J. Spencer, R. A. Taussig, A. B. Upton, D. S. Culver, W. B. Welles, G. A. Leland, C. F. McComb, J. K. Redington, C. K. Lawrence, M. W. Bates.

**Wenona Iron Company**; Duluth; $50,000: 500 shares; Aug. 20, 1891. W. H. Fisher, D. H. Merritt, J. H. Upham, L. Merritt, W. A. Barr.

**West Gogebic Iron Land Company**; Minneapolis; $60,000; April 20, 1891. M. W. Lewis, J. A. Wolverton, F. B. Lewis.

**Wyoming Iron Company**; Duluth; $300,000; 3,000 shares; April 23, 1892. F. Cox, S. W. Eckman, W. F. Gore.

**Youngstown Iron Company**; Duluth; $3,000,000; 30,000 shares; March 1, 1892. A. Merritt, N. B. Merritt, A. L. Warner, C. C. Merritt, B. T. Hale.

**Zenith Iron Company**; Duluth; $2,500,000; 100,000 shares; March 28, 1892. G. F. Piper, H. H. Hanford, L. E. Judson, Jr.

## METHOD AND COST OF MINING ON THE MESABI.

The excellent quality of the Mesabi ore and the large amount of it have been commented upon in the preceding pages. A few words as to the expense and probable method of extracting this ore from its bed and placing it on the cars ready for transportation to the furnace will be of interest. In an article in the Cleveland Iron Trade Review, July 21, 1892, the writer made the following statements:

"The most important feature of the Mesabi, in view of its distance from the furnace and forced competition with other ranges, is the cheapness of mining. A few estimates will make this clear. Old methods and old calculations will not answer on this range.

"Soft ore, large areas near the surface and horizontal deposits are not to be handled by deep shafts, air-compressors, timbering and costly pumps. It is the exception to find the ore covered by rock, and it is unusual to find more than fifty feet of glacial drift lying upon it. It is not to be supposed that there will be only a single method of mining here. Different men will have different ideas, and different properties will present different problems, but it is plain that the most of the mines will be worked as open pits, with the surface stripped off.

"Estimates of the cost of removing earth, sand, clay and gravel and boulders can be obtained from any railroad contractor. The estimated cost per cubic yard varies from six to forty cents according to the material and the facilities for removing it. With a railroad at hand a steam shovel will remove ordinary sand and gravel for six cents a yard. By hand work, without railroad facilities, it will cost from twenty-five to forty cents a yard.

"When the surface is stripped off, the ore is found in flat deposits covering twenty to sixty or more acres, and from twenty to ninety feet thick. Test pits are sunk in places one hundred and seventeen feet deep by pick and shovel, without a single drill hole or blast of powder. In other spots there may be twenty or thirty feet in a pit which is too hard to pick. This can be thrown down in large quantities when there is once a face on it, and can then be loaded by hand or steam shovel. Where no blasting is required, the expense of loading cars by hand labor will not exceed twenty-five cents per ton; by steam shovel it may reach ten cents. Where the ore is hard enough to blast, the expense of excavating and loading on cars may reach forty cents. It is not necessary to reckon into our calculation any interest on a large investment, for that is covered by royalty. No expensive plant is depreciating on our hands. Fewer damage suits arise from injuries received, because our men work by daylight.

"Let us now, with these figures before us, make a theoretical estimate of the cost of mining ore on almost any property on the Mesabi which has been developed enough to show the depth of ore and the amount of stripping. One cubic yard of ore weighs about two and one-half tons, one yard of earth about one ton. The average depth of ore so far revealed on several properties is seventy feet, and the surface thirty-five feet. In other places the ore is sixty or even eighty feet thick and the surface only twenty, but for the sake of estimation let us consider the ore only twice as thick as the surface. There are then two cubic yards of ore for each cubic yard of surface. But as each yard of ore weighs two and one-half tons there are five tons of ore for each yard of surface, and if the stripping costs the maximum of forty cents per yard the cost for each ton of ore is eight cents. At the minimum of six cents per yard for stripping, the stripping cost is only one and one-fifth cents for each ton of ore.

"When the surface is removed the ore is practically in a huge stockpile, containing in some instances several millions of tons. At the maximum cost of mining this by hand and in hard ore the cost of stripping and placing ore on cars is forty-eight cents per ton. The minimum cost at the figures given above is eleven and one-fifth cents. The average is about twenty-nine and one half cents. But as there is more soft ore than hard the average may be expected to be about twenty-five cents. The cost of timbering alone in many mines on the south shore of lake Superior exceeds the total cost of mining millions of tons of ore on the Mesabi."

If the cost of mining is 25 cents the approximate cost of the ore delivered at Cleveland will be $3.10, distributed as follows:

| | |
|---|---|
| Cost of mining, | $ .25 |
| Royalty, | .60 |
| Railroad freight to the lake, | .80 |
| Lake freight to Cleveland, | 1.20 |
| Insurance, commission, etc., | .25 |
| | $3.10 |

These items will vary somewhat. The lake tariff at present is but $1.00 to Cleveland, and in some cases the last item will be only 15 cents. The royalty, too, will vary, and will average less than 60 cents. Different methods of mining will vary in expense. The above estimate is for mining by steam shovels and stripping off the surface. If the method of underground mining is adopted the cost will exceed the figure given above.

The average price for 60 per cent. bessemer ore is not far from $4.25 at Cleveland. If the large amount of Mesabi ore made suddenly available should force the price down to $3.75 per ton, there will still be a profit for the average Mesabi mine operator.

## QUANTITY OF ORE ON THE MESABI.

How much ore is there on the new range? How long will it last? These are questions of importance and are frequently asked. The answer must be in the nature of an estimate at present. Different experts of equal skill would arrive at different results in an attempt to compute the ore in sight. Figures that represented anything like the truth, even though they were made by a competent and disinterested person, would be received with incredulity by those not familiar with the actual developments. Besides, there is no doubt that much more ore will yet be discovered; how much is merely a matter of speculation. Hardly a week passes now without the announcement of a new find, and new areas are continually being tested and found productive on the properties already under development. The Biwabik company has quite recently been presented with another mine on section 36, T. 56-18, by the good judgment and industry of their explorer, Capt. J. G. Cohoe. The number of known merchantable deposits already exceeds twenty and many other promising localities have not yet been explored.

It is evident that there is ore in store for many years to come, and that permanent investments and improvements of the most extensive nature can safely be made, based on an expectation of the sufficiency and quality of this ore-supply. As already stated contracts have been made calling for the minimum production of one and a half million tons per annum. This is eighty per cent. more than has ever been produced by the Vermilion range in one season, and is about one-sixth of the entire lake Superior product. The yield of some of the largest mines, like the Mountain Iron, McKinley and Lake Superior, is not included in this minimum figure, nor are some others like the Canton, Kanawha and Great Western. It is moreover likely that some companies will ship more than their minimum amount. It may not be within the first two years, but after they are quite ready.

## TRANSPORTATION.

Extensive railroad and vessel equipments are necessary for handling the product of an iron range. It seems rather questionable whether the railroads running to the Mesabi will be able to handle the ore which will be offered them in 1893. The iron mines are situated sixty to eighty miles from lake Superior. At the beginning of 1892 there was but one railroad, the Duluth and Iron Range, which crossed the Mesabi, and that was twelve miles from the nearest mine. The Duluth and Winnipeg, in running west from Duluth, formed an acute angle with the Iron Range and crossed it at Grand Rapids, on the Mississippi river. During the first nine months of this year, however, two roads were constructed and put in daily operation between Duluth and the new range.

The first road completed was the Duluth, Missabe and Northern. From the Duluth and Winnipeg, at Stony Brook, this road runs north over a level, drift-covered region for forty-two miles to the Mountain Iron mine. The road-bed is excellent, and curves and grades being few the operating expenses will be light. It was chiefly through the efforts of the late M. B. Harrison, Leonidas Merritt, K. D. Chase and Donald Grant that this road was built. It was put in operation during the first week in October. By its contracts with the owners and lessees of several of the largest mines this railroad is already assured of large business. A considerable number of ore-cars and heavy locomotives are now being constructed for this company.

The ore brought down over the Duluth, Missabe and Northern will be handled by the Duluth and Winnipeg between Stony Brook and the docks on Allouez bay. This road will also handle ore which will be delivered to them by other branch roads to be constructed farther west. One of these roads is now being built by the Swan River Logging Company from the crossing of Swan river to the mines in townships 57–22 and 58–20.

The Duluth and Iron Range branch to the Biwabik, Canton and other mines near the town of Merritt was also completed in October, 1892. In spite of many serious natural obstacles, such as heavy grades, this road has as fine a track and equipment and is as well managed as any road in the state. Its traffic is already large from the Vermilion range, and will manifestly be increased by the large output of the Mesabi. It is expected that both the Iron Range and Missabe and Northern will construct lines along the range connecting the various towns and mines.

For assistance in many ways, for valuable information and repeated courtesies, the officers of the geological survey are indebted to the Duluth and Iron Range, the St. Paul and Duluth, and the Duluth, Missabe and Northern railroad companies. The extension and successful operation of these roads, as well as others, is for the welfare and development of the wealth of the state, and they are factors perhaps second to none in forwarding its prosperity.

## VALUE TO THE STATE.

The best gauge of a nation's commercial and political rank among the nations of the world is found in the record of its mining and manufacturing achievements. The country that makes the largest use of its natural products is the leader in all that constitutes national greatness. One good reason for the decadence of nations formerly foremost in the world and now of but little importance is the want of mineral resources or the ability to utilize them.

We may go farther and say that of all natural resources there is none which, properly developed and applied, confers such great riches and commercial importance on its possessor and user as ron. Gold and silver mines are valuable and their possession enriches nations as well as individuals, but "he who possesses iron will soon be master of the gold," and its benefits to civilization are greater and far more lasting.

Which are the leading countries in the world to-day? The United States and England are probably foremost in all that denotes prosperity and greatness. Which are the largest producers and consumers of iron ore? The same two by long odds, having yielded together more than fifty per cent. of the world's output in the year 1889.

The same truth is borne out by a consideration of the different States of the United States. The four most populous and wealthy States in the Union are New York, Pennsylvania, Illinois and Ohio. In 1890 these four States ranked respectively fifth, first, fourth and third in the production of pig iron, having produced in the aggregate 73.5 per cent. of the entire yield of the United States. In the production of steel they ranked in the same order.

In Michigan, Wisconsin and Minnesota there was an average increase in population amounting to forty-one per cent. in the decade from 1880 to 1890. In these States the production of iron ore increased in a more than corresponding ratio. The average increase of Michigan and Wisconsin was 1210 per cent., while Minnesota, which did not appear as a producer in the tenth census, ranks *fifth* among the States in the eleventh. These commonwealths have not derived their full benefit from this large production of iron ore for two reasons. First, they have been producers but a few years. Second, their ore has been shipped away to be consumed in other regions; and it is not merely the production of iron ore, but the combined production and consumption or manufacture of iron that results in the greatest growth and prosperity.

With the exploitation of the mines on the Mesabi there will arise communities of inhabitants who will populate the northern portion of the state more rapidly than would be the case for almost any other reason. All the industries connected with mining and the support of a large number of people will be rapidly promoted. But the greatest good will come only from the establishment of furnaces to reduce the ore and factories to make finished articles for shipment to the western markets.

Minnesota has within her borders the greatest iron district known in the world to-day. It lies within her power to become the leading state in America. With these facts before them it is incumbent upon the citizens of this commonwealth to consider most seriously how to derive the greatest benefits from her mineral wealth. It is a sober fact that more merchantable iron ore is already known to exist on the Mesabi range than has been produced from all the other mines in the lake Superior region since they were first discovered. With this possibility of unprecedented prosperity and industrial growth every facility and inducement should be extended to those who may establish furnaces and factories within our boundaries.

Discoveries of ore on lands owned and leased by the State already promise an annual income of a quarter of a million, to be paid directly into the State treasury in the shape of royalties. The erection of blast furnaces to consume this ore would result in benefits to the state at large equal to several times the amount of these royalties. It might be a wise move on the part of the State to pay a bounty on each ton of ore reduced within her limits. If this bounty were simply enough to offset the royalty it would be a considerable inducement for the establishment of furnaces, and would be a paying investment for the State.

## CLASSIFICATION OF THE THEORIES OF THE ORIGIN OF IRON ORES.[‡]

In discussing the various theories proposed for the origin of iron ores in Bulletin No. 6, the scheme or order adopted by Prof. A. A. Julien was followed. It has not proven entirely satisfactory, being often inconvenient and confusing. The following classification may be used in the study of the subject with a clearer understanding of the differences in the ideas entertained by geologists on this interesting question:

- A. MECHANICAL.
  - a. Extra-terrestrial or cosmical.
    - 1. Meteoric fall. [1.][†]
  - b. Terrestrial.
    - 1. Subterranean—eruption in dykes or accompanying basaltic flows. [2.]
    - 2. Superficial action.
      - *a.* Violent abrasion and transport. [13.]
      - *b.* Ordinary erosion. { 1. Concentration of iron sands. [14.] 2. Oceanic sedimentation. [8.]
- B. CHEMICAL.
  - a. Changes in situ.
    - 1. Change in the kind or quantity of iron already present in the rocks.
      - *a.* Alteration of diffused ferric oxide into ferrous carbonate. [10.
      - *b.* Metamorphism of bog ore. [11.]
      - c. Metamorphism of lake ore. [12.]
      - *d.* Alteration of ferrous carbonate or sulphide into ferric oxide. [8 in part.]
    - 2. Change in the kind or quantity of other minerals.
      - *a.* Substitution of iron oxide for some non-ferriferous mineral. [17.]
      - *b.* Concentration, by removal of other constituents. [4.]. Similar to B a 1.

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[‡] American Geologist, Nov., 1892, Vol. X., No. 5, p. 277.

[†] Figures in brackets refer to the theories as numbered and discussed in "The Iron Ores of Minnesota," Bulletin No. 6, Minn. Geol. Survey.

c. Electro-telluric action. [16.]
b. Removal by chemical action and subsequent deposition.
1. By action of heat—sublimation. [3.]
2. By action of water.
- *a.* In drainage basins.
  - 1. Oceanic precipitation. [8 in part.]
  - 2.
    - a. Secondary product of the decomposition of basic rocks [18.]
    - b. Secondary product from the decomposition of pyrite. [7.]
- *b.* In the rocks.
  - 1. Saturation of porous strata. [5.]
  - 2. Infiltration into cavities. [6, 15.]
- *c.* Deposit by springs. [9.]

### COAL IN NORTHERN MINNESOTA.

During the past year there have been frequent reports of the discovery of coal in the region north of Duluth. The development of such extensive iron mines and the great desirability of coal deposits that can be used in connection with the iron has added to the interest with which such reports are usually received.

The opinion of the state geologist and the writer has been frequently expressed that the only coal of any sort in the northern part of the state is in thin seams of brown coal, occuring in Cretaceous shales, which were found in patches on the Little Fork river by the writer in 1888. This coal is not of good quality and the discovery of large amounts in thick beds would not be of such great importance as the newspapers would have us believe.

At the same time lignite is used to a considerable extent in treeless regions as fuel for ordinary heating and cooking purposes. In Texas and Dakota such coal is mined in considerable quantities. Grates of a particular pattern are devised in which to burn this coal and it plays quite an important part in the domestic economy of those regions. It is used in the form of briquettes in Germany. These briquettes are made by drying the brown coal until the water it contains is nearly all driven off and then subjecting a mass of it to a pressure of fifteen hundred to two thousand atmospheres. The resulting briquette is elliptical in form, about six inches long and one inch thick. It is so hard that it will not absorb moisture even though laid in water for some time. This coal is too fine-grained and not compact enough to use in blast furnace practice. If this brown coal should be found dehydrated and consolidated by heat or pressure consequent on eruptions or excessive faulting in the rocks, it would have a much greater value. It is not impossible that such deposits may be found in some of the large areas northwest of Duluth as yet but little explored by the geological survey. It is quite desirable that some further examination be made of this region in connection with more thorough and careful mapping of the rocks of the Mesabi range. The value of good coal deposits cannot be overestimated, and if we have such in Minnesota the sooner we know it the better.

## V.

# SKETCH OF THE
# Coastal Topography of the North Side
# OF
# LAKE SUPERIOR

## With Special Reference to the Abandoned Strands
## OF
## LAKE WARREN

(The Greatest of the Late Quaternary Lakes of
North America)

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BY ANDREW C. LAWSON,
Associate Professor of Geology and Mineralogy in the University of California.

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# INTRODUCTION.

The prosecution of geological investigations for the Geological Survey of Canada in the region northwest of lake Superior afforded the writer annual opportunities of obtaining cursory glimpses of the coast of the great inland sea itself, and on a few occasions of making a very limited reconnaissance of particular portions of it. He never, however, had the good fortune to be able to examine its geological features in detail. Those features, even to his limited acquaintance with them, appeared ever both grand and simple, and seemed to yield to mere inspection an exposition of the great principles of physical geology, which in force and clearness was second to none he had met with either in reading or in traveling.

Working gradually eastward, therefore, the writer had before him the prospect of some day entering upon the investigation of that interesting and rarely paralleled line of accessible rock exposure, the "north shore" of lake Superior, and of presenting a detailed account of the relations there revealed as a contribution to geological science. The severance of his connection with the Canadian survey in the spring of 1890 obscured this prospect, but the writer's thoughts still turned in that direction. In the following year after having settled at the University of California, it seemed to be advisable, before engaging in new investigations on the Pacific coast, to revisit lake Superior for the purpose of procuring information relative to some minor geological problems, which had been suggested to the writer in the course of such partial and unsatisfactory examinations as he had formerly been able to make. Among these problems was an inquiry into the character of the ancient shore lines of the lake. Stimulated by the interesting results obtained by Upham and Tyrrell in the lake Agassiz basin to the west and by Gilbert and Spencer in the lake Ontario (Iroquois) region to the east as to the deformation of ancient shore lines, the writer had been particularly attracted by the evidence of former high elevations of the lake; and had made some effort to gain definite information as to the distribution of terraces and beaches, and as to the probability of a detailed inquiry yielding sufficient data for purposes of generalization.

The interest and importance of such an inquiry lies, of course, in the evidence which it affords of local instability of the crust of the earth. On oceanic coast lines evidences of recent differential movements of the crust are ordinarily not difficult to observe. Such movements are not confined to the vicinity of these coasts but are probably common in the interior as well as on their periphery. But the evidence which makes this statement possible has until recent years been very meagre, and indeed, scarcely sufficient to satisfy the demands of exact knowledge. In the interior of the continents there is no absolute datum such as is offered by the surface of the ocean to which may be conveniently referred the altitudes of the land. There is not a set of agencies, such as the shore action of the sea, to score on the slopes a definite horizon that may be readily recognized as out of place when lifted beyond the reach of those agencies. The allied action of lake shores produces similar horizontal impressions, but the lake may go up or down with the portion of the continent in which it lies and otherwise share its movements, so that when such horizontal shore lines are seen high above the waters of a lake they are usually left there by the mere subsidence of the level of the lake. Thus there is no means of measuring the *absolute* vertical movement of any portion of the interior of a continent, except by the laborious and costly method of carrying lines of levels to the sea shore. But for the more immediate purposes of geological science the absolute measure of such movements is not needed. The science will be enriched in proportion as means are discovered recognizing the fact of recent *differential* vertical movements of the crust in regions remote from the sea and of affording some approximate measure of their extent without reference to any absolute datum. Such a means has been supplied by the modern study of the development of topographic forms, a study that, thanks to the masterly lines that have been laid down by Gilbert, Davis, McGee, Chamberlin and other leaders of the present time, bids fair to become one of the most important fields of research to engage the attention of the coming generation of American geologists.

As one result of such topographic studies it appears that in interior regions we may have good evidence both of the fact and of the measure of differential movements of the crust in (1), the character of stream erosion and deposition, and (2), the deformation of the abandoned shore lines of lakes. It is now generally recognized that streams are extremely sensitive to any change in the slope of their trenches or of any portions of them. There is a uniform minimum slope which they constantly seek to establish and maintain. Any movement of the land leaves its record in a change in the intensity of the action of the stream, whether it be cutting or depositing; and in non-glaciated regions streams are now systematically inspected by geologists for the purpose of ascertaining whether the country traversed by them has been uplifted or depressed, or has maintained a fairly constant altitude. Evidence of this kind is, however, not always available.

The peculiar topography of certain regions is due to the fact of their having been occupied in comparatively recent times by lakes which have now wholly or partially disappeared. One of the characteristic features of such a topography is the presence of ancient shores of the lake at various altitudes on the slopes of the basin, marking as many stages of the water. These strand lines are often traceable as contours for hundreds of miles, and in some cases, as for example on lake Bonneville, the highest of such strand lines is a sharp demarkation between two classes of topography, the one that of the once submerged basin and the other that of the hills above the highest level of the lake. These strand lines were once of course horizontal. At the present day they are frequently found to vary from horizontality in a marked degree, and in this case they are said to have suffered deformation. This deformation affords us at once a proof and an approximate measure of the local differental movements of the crust. Among the most remarkable instances of such deformation of ancient shores are the cases of lakes Agassiz and Iroquois; the former a glacial or post-glacial extension of lake Winnepeg, and the latter a corresponding extension of lakes Ontario, Erie and Huron.

The ancient shore lines of lake Agassiz have been traced by Upham and Tyrrell on the front of the Pembina escarpment in practical continuity for many hundreds of miles on the open prairie, and are found to ascend to the northward at the rate of from six to sixteen inches to the mile.

The measurements of Gilbert and Spencer on the ancient strand lines of lake Iroquois show that they slope in a similar fashion. Thus there is very explicit evidence of the differential movement of the land surface of North America in two extensive regions lying on either side of the lake Superior basin. In view of this fact it becomes a matter of very considerable interest to ascertain what evidences the ancient strand lines of lake Superior afford of differental crustal movements. This was the motive of the present inquiry. The fact of the former high elevation of lake Superior has long been known, though not to the extent to which the writer is now able to establish.

Logan in his report of the geological survey of Canada, 1847, records the occurrence of terraces below the Petits Ecrits (Terrace bay) rising to an elevation of 331 feet above the lake. Terraces rising to nearly 100 feet on the south side of the lake were described and their significance appreciated in Foster and Whitney's "Report on the Geology and Topography of a portion of the Lake Superior Land District," Part I, 1850, and Agassiz in his "Lake Superior," 1850, discusses the terraces observed by him in his trip around the "north shore" and cites Logan's measurements.

But while the former high elevation of the lake was known, no effort whatever had been made to trace the strands around the coast and no suggestion had been offered as to whether they maintained their original horizontality or had been thrown into inclined attitudes. There was thus a serious gap in our knowledge which, it is hoped, will be in some measure filled by the information contained in this paper.

At the outset of the inquiry it was proposed simply to secure accurate data as to the altitude of the various strand lines at as many points as possible and to gather evidence which would help to trace particular strands around the coast. As soon as the work was begun, however, a comparison was naturally instituted between the characters of the present strand and those of the ancient and abandoned strands, the altitudes of which were sought.

This led to a consideration of the topography, not only of the immediate shore line, but also of the general coast of the north side of the lake. It was found that the coast presented very striking contrasts of topographical character which were due to marked differences in the petrographical and structural geology of its different portions. Thus, in the course of the search for elevated beaches and terraces, sufficient information was gained to serve for a general sketch of the topography of the north coast of the lake from Duluth to Sault Ste. Marie. The ancient strands of the lake are now simply topographic features which are, for the most part, displayed along the coast at no great distance from the shore. It seemed best, therefore, to include the discussion of these special features in a more general discussion of the topography of the coast. This discussion does not pretend to be in any sense exhaustive. It is a mere sketch which would be unwarranted were there any satisfactory account of the topography of the north side of lake Superior to be found in geological literature. Even as a sketch this description of the general topography of the coast suffers from the haste in which the work was done, the entire trip from Duluth to Sault Ste. Marie occupying only two months; and also from the fact that the writer had no special qualifications for the work other than his general familiarity with the geology of a portion of the region. It is hoped, however, that the exact data which have been obtained regarding as many of the ancient strands of the lake as could be seen from off its present shore will compensate for what may be lacking in the general account of the coast; and that what is here set forth may be an incentive to others to make more detailed and therefore more valuable examinations of its various parts.

## GEOLOGICAL PROVINCES FRONTING ON LAKE SUPERIOR.

There is a very evident relationship between the general topography of the north side of lake Superior and the geological conditions which obtain in different portions of its extent. Between Duluth and Sault Ste. Marie there are four great geological provinces fronting on the lake. These are the Keweenian, the Animikie, the Archæan and the Potsdam.

The Keweenian occupies the entire Minnesota coast from Duluth to Grand Portage. Beyond this point the various formations of the Keweenian are probably geologically continuous around the whole of the north shore, but the out-crop of the rocks is mostly confined to the islands which fringe the coast and to the peninsulas terminating in Thunder cape and Magnet point, which are here regarded as part of the island fringe rather than of the main land. A few outlying patches are also found at different points on the main shore, but these are quite limited in extent except in the vicinity of Nipigon, where a neck of these formations connects the lake Superior Keweenian basin with the extensive interior Keweenian basin of lake Nipigon.

The Animikie rocks occupy the main shore of the lake uninterruptedly from Grand Portage to Port Arthur and also the chain of islands which stretches from Pigeon point to Thunder cape. From Port Arthur onward to the meridian of the Slate islands the Animikie formations are geologically continuous, but are much interrupted along the shore by projecting areas of the underlying Archæan, and, on the peninsulas between Thunder bay and Nipigon bay, by overlying sheets of the Keweenian.

The Archæan shares the coast line with the Animikie and Keweenian from the vicinity of Port Arthur to the eastern end of Nipigon bay. Beyond Nipigon bay as far as the outlet of the lake the coast yields to the rugged dominion of the Archæan; the only exceptions being the Keweenian outliers of Gargantua and Mamainse and the flat-lying patches of Potsdam in the vicinity of Goulai's bay and Sault Ste. Marie.

These Potsdam formations constitute the fourth geological province; and, although its extent on the lake shore is very limited, the rocks composing it have an extensive distribution as is shown by their presence on several of the larger islands off this part of the coast, and much of the character of the southeasterly part of the lake is due to their presence. The Potsdam sandstones are also of peculiar interest, inasmuch as they form the dam in the St. Mary's river which holds the waters of the lake at their present level;—a dam which has evidently only recently been rendered functional by the lowering of the waters of lake Huron below the level once occupied in common by that lake and lake Superior.

Corresponding to each of these great geological provinces, there is a distinct type of coastal topography. And here it may be well to draw a distinction between those elements of the topography, which from Gilbert's classic work have come to be regarded as the "topographic features of lake shores" and what may more comprehensively be designated the *coastal topography*. On any rocky coast line of a lake there may be developed certain topographic elements, the perfection of form of which may be evolved practically independently of the varying character of the geological conditions of the coast. Of these topographic elements we have beaches, bars, spits, terraces, sea-cliffs, caves, pot holes, etc. These are the direct product of wave action along the shore and may be common to all lakes. They will therefore be referred to briefly as the "shore features." The term "coastal topography" embraces these and also those features which, though not necessarily developed by shore action, are well displayed along the coast line and are of a local character and peculiar to any given lake or to several lakes existing under similar geological and physiographic conditions.

Just what should be comprised under the designation "coast" is somewhat difficult of definition. That there is, however, a definite belt of the land extending back from the shore to a varying extent, which is commonly recognized as the coast, goes without saying. The area recognized by the U. S. coast and geodetic survey as the "coast" appears to be that portion of the land visible from a ship sailing within easy distance of the shore. It may also be generally described as the more or less rudely beveled edge of a continental tract where it breaks away in altitude to form the margin of a topographic basin occupied by water.

The coastal topography, then, of lake Superior, as thus understood, is determined in each geological province by the conditions peculiar to that province. Even the common "shore features," such as beaches and wave built terraces, although found in equal perfection of form in different provinces, are clearly affected by the geological conditions, and their development is not always simply a question of a given amount of wind and water and time. The material of which they are constructed is, for example, largely extra-lacustrine in its derivation. The waves supply themselves often with but a subordinate proportion of the materials which they employ in the construction of topographic forms, particularly along the front of the Archæan province. The great bulk of the material is brought down by stream action and sub-aerial agencies. The abundance of this material and, therefore, the number and aggregate extent of beaches, bars, spits and terraces, varies directly with the character of the rocks and with the presence or absence of morainic accumulations.

The depth of water and the angle of the sub-aqueous slope also are conditions which materially affect the development of such structures, and both of these conditions vary with the geological character of the shore. It will thus be found that the "shore features" proper vary as to their abundance and extent according to the readiness with which the rocks of any given province yield the materials for construction, and according as the sub-aqueous slope is favorable or the reverse. Other conditions are the character of the streams entering the lake and the time during which the lake has remained at the same level. The latter is, however, a condition which is a constant quantity for all parts of the shore of the lake. But these "shore features" proper are but small and subordinate elements of the sum total of the coastal topography of the north shore of lake Superior.

A very important feature of the topography, and one strictly dependent upon the character of the rocks, is the shore contour or the line of intersection of the coastal slope and the surface of the water. This embraces both the general form of the lake or the trend of its shores, and the sinuosities and indentations subordinate to that general trend. The general trend of the north shore of lake Superior, although a dominant element of the topography, has practically no relation to littoral forces; and even the detailed forms and minor sinuosities of the contour are ascribable on these rocky coasts only in part to differential erosion, a major portion representing simply a horizontal section through pre-existing forms.

Another feature of scarcely less prominence on the coast is that which becomes apparent in longitudinal profiles along the mean local trend of the shore. Such profiles indicate the hight and boldness of the promontories, headlands and minor projections of the coast. The breadth of such features is also shown, but this dimension is better read off from the shore contour where the variation is apparent. The character of the profile may, like the details of the shore contour, be due either to differential shore erosion or to the submergence of pre-lacustrine forms. On lake Superior these profiles are for the most part vertical sections of partially submerged forms which antedate the lake, and their aspect is peculiar to each of the geological provinces.

Still another feature of the coastal topography, and the most important for the purposes of an inquiry into ancient shore lines, is that which is best represented by series of profiles transverse to the shore. It is that element of the topography which is dependent upon the hight of the land in the vicinity of the shore contours and upon the shoreward slope, which slope may be modified by the presence of shore features developed at levels of the lake now abandoned. For very considerable stretches of the coast, however, these modifying features are absent, the bald rocky slopes having retained no impression of former occupation by the waters of the lake; and in this case the transverse profile is practically independent of littoral action. In order to make clear to what extent these various elements of the coastal topography are dependent upon the conditions peculiar to each geological province, it will be necessary to review briefly the structure of the entire coast.

## GEOLOGICAL AND PHYSIOGRAPHIC CONDITIONS PECULIAR TO EACH PROVINCE.

The Keweenian from Duluth to Grand Portage consists essentially of a well stratified series of volcanic flows, having a gentle, but very constant, lakeward dip, which does not exceed as a general rule ten degrees. The sedimentary formations are represented also in the series, but only to a very limited extent, and occupy less than one-half per cent. of the coast line between the points above mentioned.

The pre-Keweenian surface upon which the series rests is exposed at a number of points on the shore, but its exposure at any one place is comparatively small. The rocks of which it is composed are massive, coarse-grained, granular aggregates of labradorite *and are similar to rocks which are well known in the Archæan. They are doubtless Archæan inliers within the Keweenian province, and they exhibit all the evidences of profound erosion and rounding which the Archæan shows at other points on lake Superior where overlapped by the Keweenian.

Since the time of their outflow over this surface of presumably Archæan rocks, the Keweenian strata have not suffered any disturbance sufficient to fold or even to tilt them to any noteworthy extent. The prevaling lakeward dip at low angles is probably partly due to the altitude of the slope over which the lavas flowed, rather than entirely to a differential movement of once horizontal strata.

But, while the Keweenian formations have remained almost exempt from disturbances of this kind, they have been profoundly affected in another way, and the geological structure is more complex than might be inferred from the simple statement of the composition of the series as above given.

The series has been invaded by very many later intrusive masses, which appear along the line of the present coast either as dykes, or, more commonly, as injected sills; while there are also not a few masses of igneous rocks which, considering the very limited study that has been given to the geology of the coast, it would be rash to place definitely either with the regular bedded constituents of the series or with the later masses which cut it, although they doubtless belong to one or the other of these categories. The dykes usually do not vary much from the vertical, and the intrusive sills coincide with the planes of stratification of the bedded flows.

Very large portions of the rocks of the Keweenian series are vesicular or amygdaloidal in character, and many, particularly those of an acid composition in which the vesicular structure is not as well developed as in the more basic flows, are traversed by irregular joints to so remarkable a degree that it is scarcely possible to secure the smallest hand specimen the form of which is not conditioned by joint planes.

There appears to be no great contrast in hardness or in power of resisting disintegration between the Keweenian strata and the intrusive masses which cut them. The basic intrusives afford evidence, however, of being more decomposable and the acid masses

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*These rocks, here styled Archæan, are in the horizon of the gabbro and its associated crystallines, included by the Wisconsin and Minnesota geologists in the base of the Keweenian; although, by the Canadian geologists, generally considered "Laurentian." See A. A. A. Sci., Boston, 1880, p. 425, and ninth Ann. Rep., Geol. and Nat. Hist. Survey Minn., p. 387. [N. H. W.]

of being less so, than the bedded rocks. Faults which can be clearly recognized as such are not prominent, although certain blocks of strata with precipitous fronts and gently sloping backs, which are observable some miles inland in the vicinity of Poplar river, suggest the presence of faults with oragraphic tilting. It is not improbable, moreover, that the entire Minnesota shore with its persistent line of cliffs follows the line of a fault scarp. The intrusive sills usually appear at an altitude which is about the present level of the lake or but slightly above it.

To these broad geological features there remains to be added a statement of three important physiographic facts in order to have before us the salient conditions which have controlled the development of the peculiar topography of the Minnesota coast. The first of these is that, if we except the drainage of the St. Louis river, the hydrographic area of Minnesota which is tributary to lake Superior is a comparatively narrow strip parallel to the shore of the lake, the water shed being a high ridge not many miles inland. As a consequence of this the streams flowing into the lake, although all rapid, and though actively deepening their trenches, are insignificant in size and bring but a small amount of material to the shore. The second physiographic condition alluded to is the rapid deepening of the water off the Minnesota coast.

The third condition is the exposure of the shore to the open expanse of the lake without the protection of any material breakwaters.

The Animikie rocks are geologically older than the Keweenian and underlie them. The emergence of the Animikie from beneath the Keweenian may be easily observed in the vicinity of Grand Portage as has been well described by Irving. The lower series presents several striking contrasts with the higher, the most important of which is due to the diverse character of the rocks. While the Keweenian is made up almost entirely of volcanic flows, the Animikie is composed altogether of sedimentary strata with no trace of contemporaneous volcanic formations. The series consists essentially of uniformily fine grained gray sandstones which locally are quartzytes, black more or less carbonaceous shales or slates, certain cherts and jaspers, beds of carbonate of iron, hematite and magnetite, a very sparing proportion of conglomerate, and occasional lenses of non-ferruginous carbonate in the slates. These rocks occur in strata which, except in local instances, as in the town of Port Arthur and near Gunflint lake, have been disturbed very little from the horizontal, the average dip of the strata being in a southeasterly direction at angles probably not exceeding five degrees; and they are frequently quite flat or very gently undulating. The rocks of the entire series, with the exception of certain of the cherts, the carbonates and the hematites and magnetites, which together form but a small proportion of the total volume, are characterized by a strongly pronounced shaly or slaty structure, the cleavage of which is parallel to the planes of bedding. This fissile character of the rocks renders them liable to rapid erosion. Were they not protected in a peculiar way little of them would have remained to the present time, and instead of forming parts of the highest and boldest cliffs on the lake they would long ago have been planed down to flat shelving forms, few of which would remain above the surface of the water. The protection which has so effectually, over large areas, enabled these rocks to withstand the active disintegration to which they are subjected, is afforded by the later intrusive masses which have invaded the series. These intrusive rocks are all basic in composition and are of the character of diabases and gabbros. They appear in the series in two distinct ways: (1) as intrusive sills or sheets lying horizontal or parallel to the stratification and resembling contemporaneous beds, for which they have by earlier observers been mistaken; (2) as vertical dykes. Some of the dykes have been observed in continuity with the sills and evidently represent the canals by which the material for the sills came up from deep sources. The most of them, however, are of later origin than the sills and intersect the latter.

The dykes have two chief trends, viz: N. E. and S. W. for the larger and more important, and about N. W. and S. E. for the smaller and less numerous dykes.

The dykes are very abundant in the vicinity of Pigeon river, and for some few miles northeast along the Canadian coast and on the islands as far as Pie island, constituting the dominent structural feature. From McKellar's point on to McKay's Mt., however, the dykes are not so prevalent and the horizontal sills have been the controlling factor in the development of the topography. These sills have very commonly a thickness of about 100 feet and in places reach 400 feet. Their altitude in the vertical column of strata varies from a position at the water's edge to elevations of over 1,000 feet, and ordinarily their position is several hundred feet above the lake.

Both dykes and sills have usually a distinct columnar structure, the columns in the former case being horizontal and in the latter vertical. This structure, of course, facilitates disintegration, but these intrusive rocks, notwithstanding this feature, are either in the form of sills or of dykes, prominently harder and more durable than the shaly strata which they penetrate.

Faulting is much more clearly recognizable in the Animikie province than in the Keweenian and is a common occurrence, many scarps being due primarily to this cause.

In this physiography the front of the Animikie province between Grand Portage and Thunder bay presents as interesting contrasts as does the geological structure. There are two considerable streams flowing into the lake over these rocks, viz: the Pigeon and the Kaministiquia, besides some minor brooks. The Pigeon contributes very little to the shore drift since its sediment is largely intercepted by lakes. The Kaministiquia has on the other hand brought down much sediment which has served for the construction of very important features. The divide is much farther removed from the lake than in Minnesota. The water off shore is also much shallower as a rule than on the Minnesota coast and there is frequently a shelving bottom. Added to this shoal water condition is the presence of a chain of islands, which form a very effectual breakwater and protect the shore from the violent action of the open lake.

The Archæan forms the basement upon which the Animikie rests in glaring unconformity. The actual superposition of the Animikie upon the well eroded Archæan surface may be observed at several points, with the Keweenian lying flat on the former. Very frequently, however, the Animikie is absent and the Keweenian is imposed directly upon the Archæan. But, whether the Archæan emerges from beneath the Animikie or the Keweenian, the contrast which its rocks present to the formations of either of the latter series is equally profound. The petrographical character and general structure of the Archæan is so different from that presented by the newer rocks which rest upon it, that comparisons on parallel lines of observation are difficult to make. Antitheses of conditions meet one at every point of view, and the topographic forms evolved under these conditions, save those due solely to wave action, present correspondingly marked contrasts.

The Archæan complex of this coast is readily resolvable into two broad divisions: (1), a great volume of profoundly altered sedimentary and volcanic rocks, characteristically schistose or in the form of massive greenstones, which have suffered intense disturbance and which correspond to what has been designated the Ontarian system*, and (2), immense batholites of irruptive gneiss and granite, which have invaded the rocks of the Ontarian system from below in the most irregular fashion, corresponding to that division of the Archæan which is commonly recognized as Laurentian. These Laurentian rocks exhibit only to a very subordinate extent those evidences of disturbances and deformation which are so abundantly apparent in the schists which they have invaded. The Laurentian gneisses and granites occupy much more of the shore than do the metamorphic and schistose rocks of the Ontarian; and each of these divisions of the Archæan province has its own peculiar phases of a topography of a general type. The entire surface of this province presents a remarkably hummocky or mammilated aspect due to pre-Paleozoic erosion[*] modified by the glacial action of the Pleistocene.[†] The rocks are fresh and free from the mantle of rotten rock arising from secular decay which covers similar crystalline rocks in some regions. The granites and gneisses, being in this fresh condition at their surface, practically homogeneous, remarkably free from divisional planes due to pressure and movement, and having prelacustrine hummocky or rounded forms which are least affected by erosive agencies, condition a topography which to a very large extent is independent of shore action. Where cut terraces are present on the coastal slopes of these rocks they have usually been carved out of morainic material or notched in the face of embankments formed early in the history of the lake. These embankments are rarely sufficiently continuous to obscure the broad aspects of the rocky slope. The schistose and greenstone rocks of the Ontarian traverse the region in curvilinear belts or zones, separating neighboring Laurentian batholites. These belts sometimes emerge on the coast in the form of great ridges, the extremities of which form promontories. They condition a much more jagged and linear aspect of topography; and along the present shore, at least, the rocks of which they are composed yield to the cutting action of the waves much more readily than do the granites and gneisses. Sometimes the trend of the coast coincides with the strike of these belts for a distance, when preciptious cliffs face the lake, which, however, are not necessarily sea-cliffs. The essentially Archæan conditions of this province are modified somewhat by a great system of diabase dykes which traverse the region and which were noted by Agassiz[‡]; they coincide remarkably closely with the trend of the coast. This coincidence of coastal trend is best seen between Nipigon and Peninsula.

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*Bull. Geol. Soc. Am., Vol. I. pp. 175-194.

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[*] *i. e.* Pre-Algonkian. (Algonkian = Animikie + Keweenian.)

[†] Bull. Geol. Soc. Am., Vol. I, pp. 163-174.

[‡] Lake Superior, its physical character, etc., 1850.

Between Peninsula and Otter head the dykes are very numerous and only a portion of them coincide with the general trend of the coast. The majority cut the line of the coast obliquely. Between Otter head and Michipicoten harbor the dykes are both parallel and transverse to the trend of the coast, there being apparently two distinct systems of fissures. The dykes do not as a rule exceed one hundred feet in width and are vertical or nearly so. When occurring in the Laurentian and where degradation has proceeded more rapidly than the country rock, a distinct trench marks their occurrence. When they traverse the Ontarian rocks they are less recognizable and less important topographically, their color being more nearly that of the country rock and their susceptibility to degradation not markedly different. Whether these lines of dykes are also fault lines has not been clearly made out. It is impossible, as has been suggested, that their origin is associated to some degree with the depression which gave rise to the lake Superior syncline.*

There is much morainic drift scattered over the coast of the lake, chiefly in the form of boulders. There are also protecting distinct morainic accumulations, although the form of these moraines is difficult to recognize on account of the timber and also from their having been modified by shore action at various stages of the lake and degraded by stream action. There are numerous streams entering the lake along the front of the Archæan province. Most of these are, however, small and the watershed is not far distant from the coast. The entire coast is well exposed to southerly and westerly storms.

The rocks of the Potsdam province are undisturbed, flat, or nearly flat, shaly sandstones, generally of a red color. These sandstones extend out from the base of the Archæan hills, which they encircle in a level plain. They have not been observed on the north side of the lake at elevations exceeding fifty feet above its level. These rocks appear to occupy an extensive tract beneath the waters of the lake in its southeastern portion. Whether on the islands or on the main land these rocks, by their petrographical uniformity, their stratigraphical simplicity and the proximity of their summits to the local base level of erosion, condition a simple and mature topography. The coast along which they are found is mostly protected from the full sweep of the lake in storms, and the water off shore is comparatively shallow.

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*Lake Superior, its physical characters, etc., 1850.

## SHORE FEATURES OF THE PRESENT STRAND.

It has been stated at the beginning of this paper that there is a very evident relationship between the coastal topography of the north side of lake Superior and the geological conditions which obtain in the various provinces which have been outlined as fronting on the lake. The shore features of the present strand constitute an important element of the general topography of the coast, and the relationship alluded to becomes very apparent in a consideration of some of these features. It is here proposed to sketch very briefly the character of the leading shore features and to compare those pertaining to the different provinces with one another, having reference chiefly to the geological conditions which have controlled the development of the shore.

### SEA CLIFFS.

Among the most striking of the shore features which engage the attention on the Minnesota coast are the lines of the low sea-cliffs, which rise abruptly from the water, ranging in elevation from a very few feet in some places up to as much as 210 feet of vertical precipice at the Palisades. These cliffs are remarkable for their great continuity, their general uniform hight and for the general scarcity of shore drift along their base. The most striking feature of the shore coutour,—viz: its simple unbroken trend,—is also a character of the cliffs and must necessarily be taken into account in a description of them. These cliffs are *seemingly* the direct product of shore action and appear from their abruptness to be in active recession; yet they are not receding altogether by reason of the process of battering and undermining to which the recession of cliffs is usually ascribable. The products of the mechanical disintegration of the cliffs do not as a rule lodge at the base of the cliff and become the tools for the further cutting of its base. Wherever such detritus lodges and is handled by the waves as a battery there is usually a little notch or vertical gash established in the cliff wall. As a rule, moreover, it is to be noted that the cliffs, independently of any softening or rounding of their brink by atmospheric agencies, are not strictly precipitous except where the rock of which they are composed is uniform from top to bottom. On the contrary, although the general effect is that of precipitous cliffs, the base is nearly always more projecting than the higher portions and the cliff rises in a series of rude steps, the front of each step being usually nearly vertical, while its surface slopes gently lakeward. The explanation of this character of cliff lies in the nature of the rocks and their structural features. As has been stated, the rocks of the coast, with some local exceptions, are volcanic flows, frequently of no great thickness, associated with which are sheets, probably injected as sills, and a few dykes. The volcanic rocks are very commonly, when basic, vesicular or amygdoloidal and, when acid, are of the nature of a dense red porphyry which disintegrates mechanically with the greatest readiness. These bedded and regularly stratified volcanic rocks have a constant lakeward dip along the whole coast, the inclination usually not exceeding ten degrees. It is these petrograpical and structural features which seem to be the real conditioning causes in the development of this remarkable line of cliffs in so far as it is actually receding, and the shore action a minor and, as it were, the determining or precipitating cause of the degradation. The bedding planes, the intricate jointage, the columnar structure of some of the beds, the porous character of many others, and lastly, the lakeward dip, all favor the loosening and dislodgement of blocks under the influence of an abundant supply of water by the waves and the changing temperature of the climate; and so the cliff recedes, being only to a limited extent worn down by the battery process. But the total recession has been very small as is evidenced by the fact that for many parts of the shore only a very narrow subaqueous shelf, disproportionate to the size of the cliff, has been formed, or none at all. And indeed there are grave doubts, amounting almost to certainty, that, although this line of precipice is now functionally a sea-cliff of the present strand, it is not primarily and genetically a sea-cliff. The way in which the cliff rises from deep water as the upward continuation of a very pronounced subaqueous cliff [See Pl. XI, Fig. 1.] indicates very clearly that its origin is essentially pre-lacustrine or at least extra-lacustrine; and the suggestion can scarcely be resisted that primarily the cliff of the Minnesota coast is a great fault scarp. Two facts may be cited which harmonize with this suggestion. (1) The trend of the coast is in direct line with the great linear series of dykes which extends from Pigeon point to Thompson island, and which probably is continuous with the similar series of dykes having the same trend on the islands and points on the south side of Thunder cape. (2) Mr. Peter McKellar has informed the writer that a great fault is observable near the head of Thunder bay in the line of the east side of the bay, and that the cliff which forms this side of the bay is without doubt a great fault scarp. This scarp would parallel the one suggested as determining the line of the present Minnesota shore, or converge upon it very obliquely.

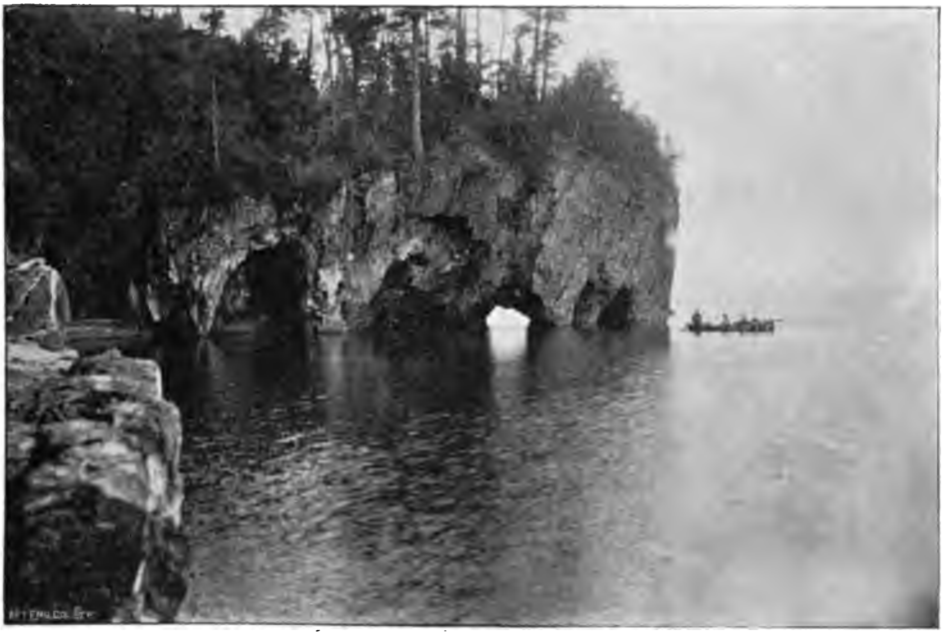

FIG 1. NATURAL ARCHWAY AT POINT OF GREAT PALISADES. ILLUSTRATING CLIFF WITH BASE BELOW WATER LEVEL. (PP. 198 AND 214.)

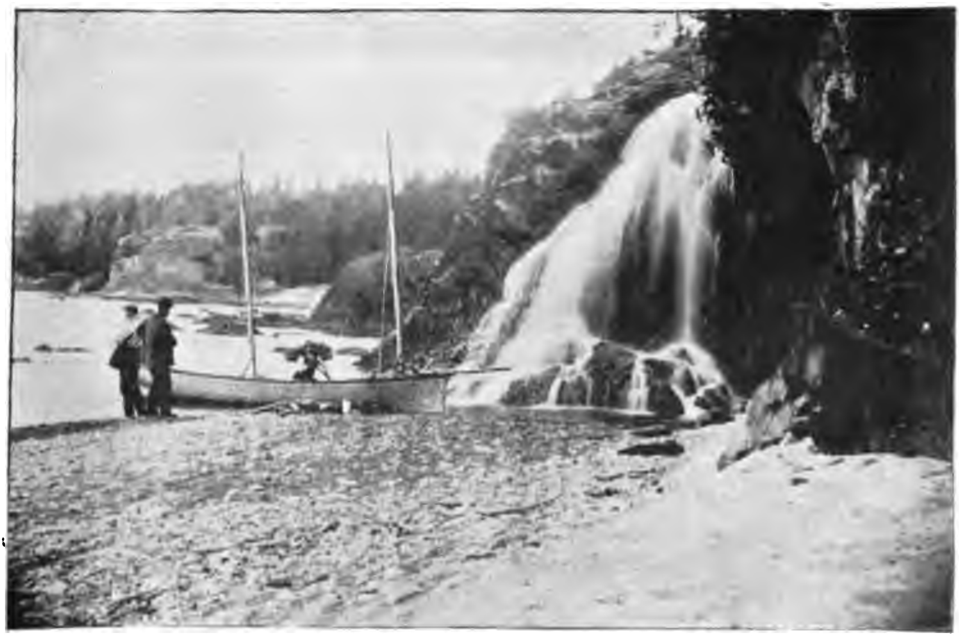

FIG. 2. SCENE AT OTTER COVE, NORTH SHORE OF LAKE SUPERIOR

Along the front of the Animikie province true sea-cliffs are not prominent or common features of the present strand. There are, indeed, numerous precipices rising from the water, but they are not all sea-cliffs in the strict sense of the term. Two types of these coastal precipices may be mentioned: (1) where the rock of the shore is that of one of the great trap dykes which intersect portions of the coast, particularly in its southwestern portion; and (2) where the thick sheets of columnar trap, which have been intruded between the nearly flat Animikie beds, descend by a gentle local dip to the water's edge. In both of these cases precipices are formed, those of the columnar flat sheets being more nearly vertical than those of the dykes. But in neither case, so far as the observation of the writer goes, are these cliffs ever functional as sea-cliffs in the sense that they are receding by reason of wave action and have a wave cut terrace at their base. Usually they rise from deep water and have no shelf at the water line. Their origin as topographic forms long antedates the lake and is ascribable to the process of erosion, which, in conjunction with orographic movements, is responsible for the basin in which the lake lies. There is, however, a type of precipice which is in its functional relations to the present strand, a true sea-cliff, although, as seems probable in the case of the Minnesota shore, the locus of the cliff was determined by other agencies than shore action. The cliff referred to is best seen on the east side of Thunder bay, above Sawyer's bay. Here the shore is at the base of a long uniform line of vertical cliff which is in active recession and which has a boulder-strewn, sub-aqueous shelf at its base. Here the face of the cliff is composed of horizontal Animikie slate, which yields readily to the battery which plays on its lower part during westerly storms. The recession is so active that it is encroaching upon a terrace of a higher stage of the lake where a similar cliff has been developed. The initiation of this line of cliff, now a sea-cliff, is, in the opinion of Mr. McKellar, expressed in conversation with the writer, due to a fault, the displacement of which is apparent near the head of Thunder bay. But these rocky precipices, whether sea-cliffs or not, do not form any very extensive portion of the shore of the Animikie province. By far the greater part of the shore is along the talus slopes of the magnificent cliffs of differential degradation, which surround the Thunder bay district and have made its topography famous. On these talus slopes earlier shores have in places constructed embankments. But, whether the present strand lies along the primary talus or along these secondary embankments, there has been no important cutting of sea-cliffs. There are a few minor instances where the shore has eaten back somewhat and given rise to a small cliff.

Along the front of the delta of the Kaministiquia there is a low but abrupt rise above the shore which is also to be interpreted as a sea-cliff. A low cliff of a very few feet encircles some of the islands, such as Flatland island, which have a small altitude above the lake in consequence of the absence of protecting dykes or sheets of trap to restrain the slates from yielding rapidly to erosion. Some of the small islets of Thunder bay also may be but the remnants of larger islands truncated at the shore line by the process of cliff-making.

Along the strand of the Archæan province rocky declivities are an almost constant feature of the shore. The coast is bold, bare and rugged; but true sea-cliffs are remarkably scarce. The rocky slopes descend to the water with usually no break in the profile and most frequently with no embankment of shore drift or appearance of shelf at their base, except in the bays where sea-cliffs in rock are not ordinarily developed on any shore. Where the shore is occupied by the Laurentian gneiss and granite practically no incision has been made in the face of the rocks at the shore line,and the surface of rock which plunges beneath the waters of the lake has with little or no qualification the precise form and slope which it had, when, earlier in the history of the lake, it was covered by several hundred feet of water, and which it had, indeed, before the existence of the lake. The entire coast has been glaciated and the glacial markings, grooves and hollows are frequently seen to pass down beneath the water's edge without an abrasion to dim their sharpness. The hummocky, rounded forms of rock which are so well displayed on many parts of the coast are the same which are found throughout the region far removed from shore action; and many of the slopes which descend to the water, whether steeply precipitous, or gently inclined or rounded in hummock form, may be indisputably recognized as precisely the slopes upon which Animikie or Keweenian sediments were deposited or over which the Keweenian lavas flowed. The basin of lake Superior is very ancient, more ancient than some glacialists have dreamed of in their philosophy. It is perhaps hardly necessary to go into the causes of this scarcity of sea-cliffs on a coast where one would at first thought expect to find them abundant, but the chief of these may be enumerated as follows: (1). The obdurate, tough and resistant character of the rocks which prevents their yielding shore drift for battering purposes. (2). The steepness of the original slope of the coast and the consequent depth of water near shore, which prevents the lodging of such shore drift as is available and hinders the building up of embankments which would facilitate the transport of shore drift to where it could be effectively used by the waves. (3). The shortness of the time at which the shore has been at its present level. Given time sufficient and the two other adverse causes would be overcome and we should have sea-cliffs around the entire coast. Where the shore lies along the schistose rocks of the Ontarian system of the Archæan, such sweeping statements as to the absence of sea-cliffs cannot be made. These rocks have certainly yielded appreciably to the cutting action of the shore and the original profiles of the pre-lacustrine forms have been notched. But the shore notch is not heavy and the recession of the fresh cliffs has usually been so slight as to modify the original profile but little, and the steep slope to the water which these schistose rocks commonly present is essentially that of the pre-lacustrine form. These cliffs in the schistose rocks may be best seen along the shore east of Otter head. On this coast, also, to the east of Dog river, may be observed a very interesting instance of the active formation of sea-cliffs in soft material, by the waves cutting into the shore embankments which have been built up at higher stages of the lake. The cliff of the present shore has been receding so rapidly that a portion of a terrace 16 feet above the level of the lake has been entirely undermined and obliterated back to and beyond its own original sea-cliff, affording a very clear picture of how gaps in the series of ancient shore lines may occur. [See Fig. 15, in descriptive notes under Dog river.]

On the shore of the Potsdam province the sea-cliff which commonly separates the shore from the plain formed by the upper surface of the flat sandstones is frequently worn down and is not always a prominent feature of the shore. It probably tends to recede more rapidly by atmospheric and organic degradation in many portions of its extent than by the attack of shore forces, so that its edge or brink is rounded and softened and the lakeward slope of the cliff is rather low. It is not precipitous on the islands.

## BEACHES, BARS, SPITS, ETC.

Boulder, pebble and shingle beaches are common features of the north shore of lake Superior, and some of these are of magnificent proportions as regards their cross profile. They are all, however, limited in their horizontal extent, except in the Potsdam province, to the pronounced indentation of the shore line. They are least abundant in the Keweenian province and most abundant in the Animikie. In the Archæan province they are only of local occurrence chiefly in the vicinity of the mouths of streams, there being extensive portions of the shore along the front of this province which yield no shore drift for the formation of such embankments. The shore of the Potsdam province presents either a continuous beach or a boulder strewn shore, but, as the Potsdam rocks are of very limited occurrence on the north side of the lake, the extent of these simple beach or bouldery strands is even here small when compared with the total length of the shore.

The extensive lines of cliffs along the shore of the Keweenian province on the Minnesota coast would seem to presuppose the occurrence of more extensive beach accumulations than are actually found; the simplicity of the shore contour, however, and its remarkable freedom from indentations in which the shore drift could lodge, militate against the development of beach embankments. The shelving character of the rocks with their constant lakeward dip, and the depth of water immediately off shore, are also effective causes in preventing accumulations of shore drift except in the most favored localities. Such localities are not wanting along the coast of Minnesota, and a few of these may be referred to.

The finest of all the lake Superior beaches is of course the bar which spans the head of the lake from Duluth to Superior City. This is so well known already that nothing more than a mere mention of it is here required. Beyond Duluth the first important beach is that which forms the bar across the mouth of the Knife river. The river has at its mouth developed a small delta in the shelter of a low point of rock. This delta material is chiefly sand, but there is mixed with it drift from the shore to the eastward. This accumulation has extended outward till it is now even with the protecting rocky point, and here it is probably stationary; having ceased its lakeward expansion by reason of the surplus being carried beyond the point. The front of this delta extends as a well defined bar almost entirely across the mouth of the stream and the waves have banked it up in the form of a broad beach.

The shore of Agate bay and that of the adjoining Burlington bay has a beach embankment of considerable extent, the pebbles being mostly of local derivation. Among these, however, were found two fragments of cream colored limestone containing fragments of fossils indicating that some of the beach material is derived from morainic accumulations.

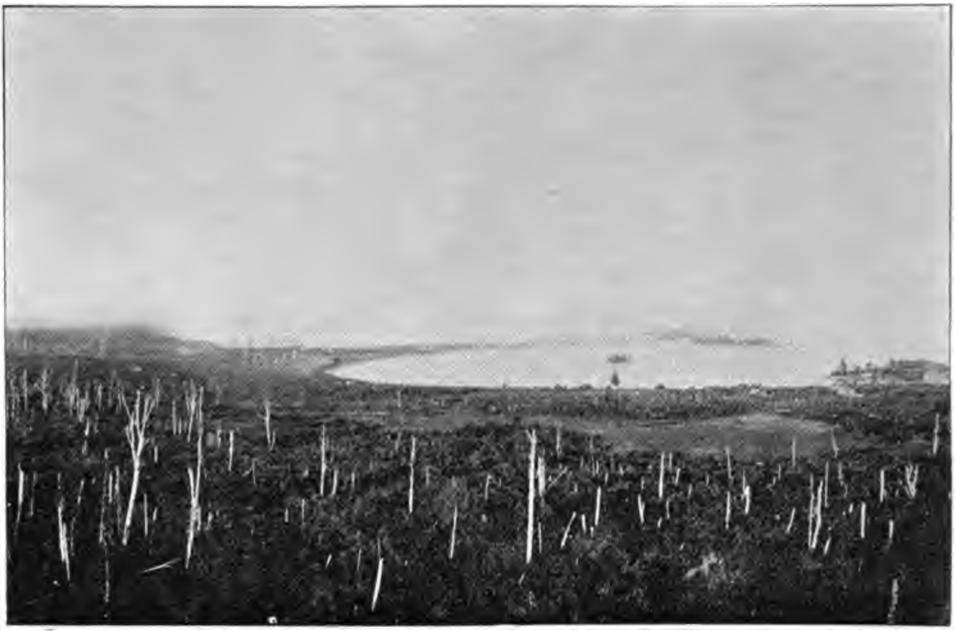

FIG 1. GRAND MARAIS. FROM TWO HUNDRED FOOT BLUFF WEST OF THE HARBOR. (PP. 203, 246.)

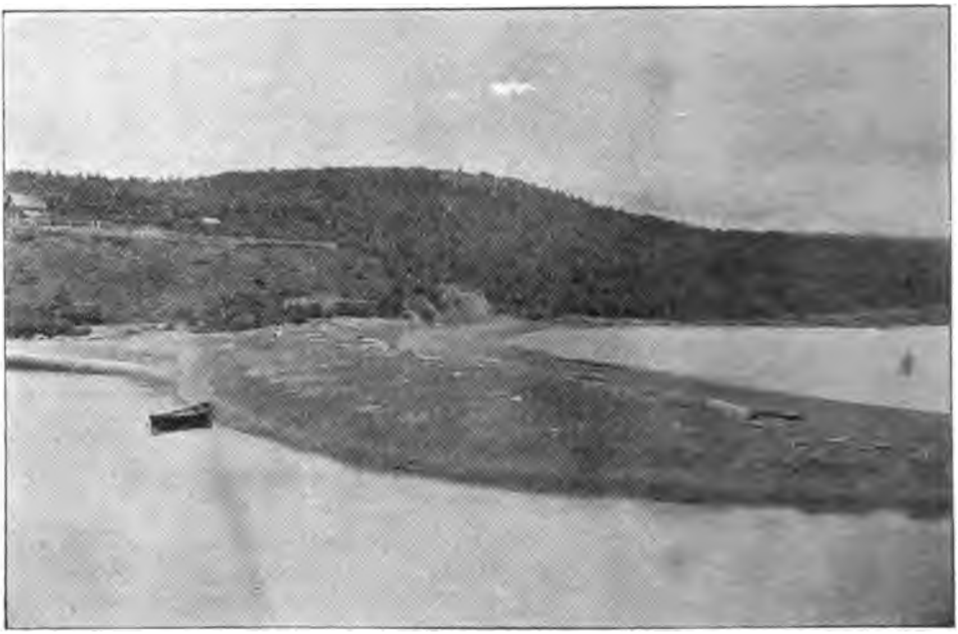

FIG. 2. SPIT AT THE MOUTH OF BEAVER RIVER. (PP. 203, 238.)

Gooseberry river discharges into a small bay which is somewhat protected by a jutting point of rock, and the shore in the vicinity of the stream presents a finely built beach of small uniform gravel of a red acid volcanic rock, which occurs in the neighborhood and which is easily broken down into small fragments without undergoing chemical decay or losing its hardness. The mouth of Split-rock river is similarly protected by Split-rock point and a beach shuts off from the lake the marshy flood plain of the stream.

The mouth of Beaver river is also well protected by a point of rock and between the stream and Beaver bay there has been thrown out a spit composed almost entirely of sand brought down by the stream. The spit is parallel to the stream and is only a few hundred yards long. The waves have built it up into a broad low arched beach. The river side of the spit is being constantly corroded by the stream and the material thus worn down is carried into the bay where it is added to the outer or lakeward side, where by the action of the wind and waves it is soon carried again over to the river side, again to be undermined by the stream. Thus there is a constant undermining on one side and up-building on the other side of the spit, while in position it remains constant. [See Pl. xii, Fig. 2.]

Between the Palisades and the mouth of Baptism river a beach of greater length than is usual on this shore has been thrown across an embankment. The material is chiefly derived from the cliffs of the vicinity, supplemented by gravel from the Baptism river, the rock there being the same red porphyry which supplies so much of the gravel of the shore drift.

At Good Harbor bay some soft sedimentary shales protected on the lakeward side by a ridge of hard igneous rock have afforded conditions favorable for shore erosion, and the bay is the result. The cliffs at the back of the bay, being of this soft shale in nearly horizontal attitudes, are actively receding and a shingle beach has been piled up along the base of the material which has not yet been reduced to clay and carried out to deep water. The beach is not large and in violent storms is doubtless entirely moved. A few miles farther on Grand Marais harbor presents a fine pebble and shingle beach which extends in the form of a broad based spit connecting the island on which the lighthouse stands with the main shore. [See Pl. xii, Fig. 1.] The material of this beach is again the same red quartz porphyry which has been so often referred to as a source of supply of shore drift. The cliff from which it is in this case derived is a little to the east of Grand Marais.

Fish-hook point, the mouth of Brule river, and Deronda bay are the only other places along the Keweenian of the Minnesota shore where notable beaches occur, and in all these cases they are found in the immediate vicinity of cliffs of red quartz porphyry and the embankments are nearly altogether composed of this material.

These beaches thus briefly alluded to are the only very prominent ones that attract attention in coasting along the shore from Duluth to Grand Portage. The longest of them is probably not more than one-eighth of a mile in length; and, if it is borne in mind that these are distributed over a shore of nearly 150 miles, their mere enumeration is sufficient to indicate the meagerness of beaches along its extent. It is not intended by this explicit allusion to these beaches to imply that there are not others. There are many small coves along the shore, so small that they afford no shelter for a row-boat, and also short stretches of open shore between jutting points, where local detritus has accumulated and has been thrown up into beach form. The proportion of these, however, to the total length of coast is very small. There are also stretches of shore which are essentially bare shelving rock, but which in patches are encumbered with boulders. In general the impression received by inspection of the Keweenian shore from a row-boat is that of a wonderful dearth of shore drift and a great extent of bare rock, and one is constantly struck by the association of the more important beach accumulations with the occurrence of a red quartz porphyry and an allied and quite similar rock in which quartz can not be detected macroscopically. This association depends upon the property which this rock has of yielding pebbles by reason of its shattered jointage structure, the resulting fragments being hard and resistant.

In passing from the Keweenian to the Animikie province along the shore of the lake one is impressed by the great contrast which is presented in the relative abundance of beaches. Along the Animikie shore beaches are the rule except where the great dykes occupy the water's edge. The reason for the difference lies in the diverse petrographical characters of the two formations. In the Keweenian the only rock capable of yielding shore drift in abundance, the red porpyrhy, is of limited occurrence, and it is prevented from yielding large quantities by its association with harder rocks which keep the line of the shore from receding. In the Animikie province it is far otherwise. The Animikie slates and slaty sandstones and quartzytes occur along the entire Animikie coast and have yielded an overwhelming amount of material eminently suitable for the formation of shingle beaches. As has been already pointed out the topography of the Animikie coast varies according as the igneous rocks which invade the slates are prevailingly dykes or prevailingly horizontal sheets or sills. At the southwestern part of the Animikie coast, in the vicinity of Pigeon river, the dykes prevail and the country is intersected by a great plexus of immense dykes, with limited patches of slates in horizontal attitudes lying between. This condition obtains also on the islands which stretch from Victoria light to, but not including, Pie island. In the portion of the coast thus affected, the dykes usually extend lakeward and as bold promontories marking off well defined bays; and the water being deep off the extremity of these promontories, the beaches are confined to the bays, so that there is not a long continuous beach on this part of the coast, although the various individual beaches in the bays are of considerable extent. Where the sides of the dykes occupy the shore, as on the north side of Pigeon point, Victoria island and Thompson island, the water is usually deep, and there is no shore drift nor beach accumulation, the cliffs (pre-lacustrine) rising precipitously from the depths of the lake. Passing into that portion of the Animikie coast where trap sills prevail and the dykes play only a very subordinate role or are absent, we find practically continuous beaches interrupted occasionally by precipitous headlands. This feature of the shore is associated with an almost entire absence of sea-cliffs. This statement may be surprising to readers familiar with the famous Thunder bay landscape with its beetling cliffs. The vertical precipices of Thunder bay overlooking the lake are not sea-cliffs of the present shore. They are primarily cliffs of differential degradation of pre-lacustrine origin, and the topographic masses which they limit are true mesas. At some of the higher stages of the lake they have been functional as sea-cliffs, but at present the subsidence of the lake has brought the shore in most cases low down on their talus slopes, and the cliffs have returned to their former condition of cliffs of differential degradation. As an exception to this last statement may be mentioned the cliffs which occupy the shore immediately to the northeast of Little Trout bay, where the main trap sheet or cap descends below the level of the lake, and its edge rises vertically 100 feet or more above the water, and there is no beach or visible talus. From these statements it will be apparent that, although beaches abound on the Animikie shore, the material of which they are composed is not derived immediately from neighboring sea-cliffs. It comes entirely from the old talus of the cliffs not now affected by shore action and much of it has come from earlier beach embankments higher up on the same talus slope.

Thus in our comparison of the Keweenian and Animikie shores we arrive at the seemingly paradoxical statement that along the former, although there are extensive lines of functionally active sea-cliffs, there is a scarcity of beaches; while along the latter, although there are practically no sea-cliffs shedding fresh detritus, shingle beaches abound.

Intermingled with the local drift of the beaches of the Animikie province there are, it should be mentioned, numerous boulders of glacial derivation. There are also many more or less angular boulders of trap from sills and dykes, and some parts of the shore are thickly strewn with such boulders to the exclusion of the ordinary pebbles and shingle.

A general statement respecting the distribution of beaches along the shore of the Archæan province is difficult to formulate. Beaches are common, but they are due to local causes and are not uniformly distributed. The intricate indentation of the coast affords everywhere ample opportunities for the lodging of shore drift and the piling of it up into beach embankments, but the supply of shore drift is very small. Where the Laurentian granite and gneisses occupy the coast shore action has been impotent both at the present and all earlier stages of the lake to affect the sculpture of sea-cliffs, which would supply the drift necessary for the accumulation of important lines of beach embankments. The schistose rocks of the Ontarian system have been more yielding, but still supply a comparatively small proportion of the shore drift. The petrography and structure of the province preclude the possibility of cliffs of differential degradation having at any previous period in the history of the region afforded a supply of talus material which might be seized by the waves and wrought up into embankments. This poverty of general shore drift and the prevalent separation of the bays by bold headlands, preventing the drift of one bay from passing around into its neighbors, conditions a shore whose beaches are dependent upon local and extra lacustrine sources of supply. These sources are chiefly two, viz: (1) stream deltas, and (2) glacial drift; and both of these are variable. The result is that the shore is a long succession of small bays, some of which have beaches and some of which have not. In the vicinity of the streams, deltas have been developed usually of small size consisting chiefly of stream pebbles, and these afford material for beaches as described in the reference to wave-built terraces. Where there are no streams the beaches, when present, consist chiefly of erratic boulders with but a sparing proportion of smaller pebbles and gravel. Thus a very small proportion of the beach material of the Archæan province is of local origin. One other source of beach material on this part of the shore remains to be mentioned. At higher levels of the lake, the streams, not having well-defined trenches of their own cutting, but following the depressions between the hummocks and hills of this mammillated region, emerged on the coast in some cases at places more or less distant from their present point of discharge, and the embankments which accumulated at these old outlets have been cut into by lower stages of the lake and the whole or part of their material carried down to lower portions of the rocky slope; and some of it enters into the composition of the modern beaches. Even when the point of discharge has not materially changed, the shore contour at higher stages was in certain other cases such that the stream detritus brought down to the lake was much more extensively distributed than at the present stage. So that not a little of the pebbly material which enters into the composition of the modern beaches is derived from the streams of the neighborhood, although this is not apparent at the first glance.

Of the beaches of the Potsdam province little remains to be said. The rocks of the Potsdam are uniformly flat, or nearly flat, often shaly sandstones; and the effect of wave action upon such rocks has been the development of a uniform and continuous shelf which is coextensive with the occupancy of the shore by these rocks, and which is now frequently occupied at the shore by a low beach. The profile of the beach of course varies according as it is sheltered or is exposed to an open expanse of water. The water off these shores is generally shallow, and wave action therefore feeble on the immediate shore, so that high beaches do not prevail. Scarps or cliffs of importance are not common, although a few good sea-cliffs occur, especially on the islands. An occasional abrupt rise of the ground may perhaps be interpreted as a cliff, genetically considered, but the rocks seem to yield readily to the degrading influence of the weather and vegetation. The shallow off shore water and the shore itself is frequently strewn with boulders which the waves are unable to handle. These boulder strewn shores are regarded as a phase of beach. Under other condidions, which would allow the access of more potent waves to the shore, these boulders would undoubtedly be ridged up together in beach fashion. The sweeping contour of the shore, the low, continuous beaches and the degradation of the cliffs, all give the shore, as has been said, an aspect of great maturity.

## DELTAS AND WAVE-BUILT TERRACES.

On the north shore of lake Superior deltas and wave-built terraces are naturally associated. The *sine qua non* of a wave-built terrace is the accession to the shore of more detritus than the forces of the shore can either transport or pulverize. On a shore where the development of cliffs has not proceeded sufficiently to yield an abundance of detritus, the only place where such a congestion of shore drift is liable to occur is in the vicinity of streams which are bringing down pebbles and boulders to the lake and there dropping them to build up a delta. Thus it happens that along the present strand of lake Superior, where the sea-cliffs are not largely developed, the chief wave-built terraces are found on the outer margins of the deltas of certain streams which are transporting coarse material, and in the vicinity of certain rocks of limited distribution which disintegrate rapidly and shed an abudance of hard fragments, as in the case of the red porphyry rocks of the Minnesota coast. Streams which are transporting sediment in a fine state of division are also forming deltas at the lake shore, but there are no wave-built terraces associated with them. Of these the delta of the Kaministiquia is the most notable. Other streams which emerge on the open coast where the water is deep close to shore are also building up deltas, but these are entirely sub-aqueous or are barely perceptible. Still other streams have their sediments intercepted by small lakes before reaching lake Superior, and these add little or nothing to the shore drift. The fewness of the deltas and wave-built terraces on the north shore renders it difficult to compare the local influences which have controlled the development of these features in the different geological provinces. There are certain general considerations, however, which may be mentioned. The extreme meagreness of the visible delta accumulations along the shore of the Keweenian province is doubtless due to the proximity of the Minnesota water-shed to the coast and the consequent smallness of the streams, and to the exceptional depth of water close to the shore line. The scarcity of wave-built terraces, which are independent of deltas, is to be ascribed to the simplicity of the shore line, which does not favor the lodging of shore drift, and to the fact that the extensive cliffs which characterize the Minnesota shore are only effective sea-cliffs to a limited extent, being probably conditioned by a pre-lacustrine structural feature.

Along the front of the Animikie province there are only two streams of importance, the Pigeon and the Kaministiquia; and of these the former appears to be a very young stream, while the latter is probably one of the oldest streams associated with the present physiography of the lake Superior basin. The one stream has a small and insignificant delta, while that of the other is large and important, as is noted more in detail below. The sediment carried by both streams is fine, and there is no wave-built terrace associated with their deltas.

The scarcity of wave-built terraces, which are strictly ascribable to the present strand of the Animikie province, is not due to any lack of shore drift, but rather to the following fact: The more recent stages of the lake have had their shores along talus slopes or earlier shore embankments, and the general shore contour for very considerable stretches has not materially changed, although the lake has subsided through many successive stages. Thus there has been opportunity afforded for such a distribution of the shore drift to be effected as to establish a practical equilibrium without tendency to transport so long as no new accessions are made to the shore; and we have seen in our discussion of the cliffs, that for the greater part of these shores the amount of shore drift is now constant, or is diminishing slowly by pulverization. In the process of establishing this approximate equilibrium, much of the shore drift has gathered inthe bays and has been ridged up into parallel beaches; but as this has proceeded *pari passu* with the lowering of the level of the lake, the ridged terrace which has resulted differs from a simple wave-built terrace in the fact that it is not level, but *slopes*, the more lakeward ridges being lower as a rule than those farther from the lake. The additions to this sloping wave-built terrace made by the present stage of the lake are not important and usually do not exceed one or two beaches.

The delta-building streams of the Archæan province seem for the most part to draw their detritus from the earlier formed embankments of the lake, through which they have cut their way; and these embankments would seem primarily to have been built up of material derived from morainic accumulations, as true sea-cliffs supplying shore drift have never at any stage of the lake been prominent features of the shore. No well characterized wave-built terraces, dissociated from deltas, have been observed along the shore of the Archæan province. In the Potsdam province there are no deltas; and no wave-built terraces were observed, although it is possible that they may be found in the bays which were not examined. Their existence is, however, improbable. A few notes are here given on the more important deltas and wave-built terraces of the north shore, based not on a careful study of their features, but only on such cursory examination as the time devoted to the work would allow.

*The Delta of the Kaministiquia.*—The largest and most impressive delta of the north side of lake Superior, as well as the most accessible for study, is that of the Kaministiquia river. The lower portion of the stream for many miles back from its mouth has cut its trench down into the delta, which has been accumulating throughout the higher stages of the lake, and this trench is continued into the lake as a sub-aqueous channel, navigable for large lake craft, through the delta now accumulating out to deep water. The river has three mouths, known as Fort William river, McKeller's river and Mission river. These embrace two islands of the older delta, the river bifurcating twice in the vicinity of the town of Fort William, about three miles from the lake shore. The material brought down by the stream is all fine, and appears to consist of clay and light sand; and this has been true far back in the history of the delta, as appears from an inspection of its structure as revealed in the trench walls of the river. This section shows uniformly for many miles from the mouth a lower portion of an indefinite thickness of blue clay, over which is spread a continuous sheet of sand which forms the surface of the ground. The blue clay has a minimum thickness at a distance of fourteen miles from the shore of probably fifty feet. The sand is not quite uniform in thickness and ordinary sections show that it ranges from two to ten feet. This structure in two strata, or two sets of strata, the material in each being quite different from that in the other, becomes easily comprehensible when we consider the two main conditions attending the development of the delta, viz: (1) The extension of the delta embankment from shallow into deep water—a condition common to all deltas; and (2) the subsidence of the base-level of erosion as the level of the lake dropped, which would cause a more rapid lakeward extension of the delta than if the base-level were constant. Of the two classes of material brought down by the stream the clay would be carried out to deep water, while the sand would be dropped in shallow water. But the shallow water at any given stage of the lake, except the highest, was deep water for the preceding stages, so that the sand for this stage would be spread out over a clay bottom. The same process would of course operate with a constant base-level, but the horizontal extension of the delta would not be nearly as rapid. The process is in operation in the growth of the delta of the present shore. The shoals from the mouth of the river on either side of the channel out to the vicinity of the Welcome islands, are sandy and have a very gentle slope, so that a sailboat may ground half a mile from shore, within hailing distance of a two thousand-ton propeller steaming up the channel, as the writer has experienced. Near the Welcome islands the slope becomes steeper and out beyond the islands is clay bottom. Thus the development of the present delta is but a continuation of the same growth which has built up the great delta extending far up the valley of the Kaministiquia. At the apex of the delta, near Kaministiquia station, its structure is different, as is indicated elsewhere; but here the condititions were different, the current was powerful and coarse material was handled by the stream. The channel of the stream near the lake is so open and unobstructed that the older portion of the delta, back of the present shore, is not subject to serious overflow, and only the subaqueous portion is growing. The slope of the older delta surface is, as it should be, away from the banks of the stream, at least on the north side towards Port Arthur. The south side of the stream has not been examined. At the line of the present shore the delta is faintly terraced by the development of a low sea-cliff, as if marking a distinct drop of the surface of the lake of a few feet.

On the surface of the subaqeous delta is an exceptionally shoal linear area between the shore and Mutton island, so that it is scarcely possible for even a row boat to pass between. This linear shoal appears to be the direct product of wave action, and the final result will doubtless be a bar connecting the island with the shore.

*The Delta of the Mazokamah.*—At the mouth of the Mazokamah river a delta of stream gravel is at present being built up. The river is a small, rapid stream issuing directly upon the lake through a narrow cañon. The latter is a sharp V-shaped cleft in the high rocky bluffs which here front the lake. On the west side the flat-lying Keweenian rises in vertical walls, and the face of the heavy sheet of columnar trap which rests upon it frowns down on the shore from an elevation of 1,000 feet or more. On the east side the Archæan rises in scarcely less formidable hills with varying slopes and much greater complexity of form. Since the removal of the ice sheet the Keweenian cliffs have been receding, while the Archæan hills have not been sensibly modified by the agencies of erosion. Although the stream is rapid, and is lowering its trench like all streams entering the present level of lake Superior, the bulk of the material which it brings to the shore is derived from a great embankment of beach gravel which has been thrown part way across the cañon at the higher stages of the lake, and which the stream is now undermining. The slides from the cut through this embankment tend to choke the stream, and it is the purging of the channel of this slide material which supplies nearly all of the pebbles for the delta now under construction. The delta which is thus accumulating on the exposed shore of Nipigon bay is not a simple delta; for the storms have given its surface, on its outer part at least, the ridged character of a wave-built terrace; and the structure throughout, as far back as the waves originally reached, is doubless a composite of that of a simple delta and a wave-built terrace, the latter being gradually dissected and overwhelmed as the delta extended lakeward. To the northwest the delta passes into a true wave-built terrace beyond the reach of the delta overflow. The entire embankment has a width from the original shore of from one-eighth to one-quarter of a mile, and is over a mile in length, extending to Mazokamah point. It has a fairly uniform level, except near the mouth of the stream, of from three to six feet above the lake.

*The Delta of Nipigon River.*—The Nipigon is the largest stream flowing into lake Superior, yet its present delta is small and unimportant as a feature of the present strand. We have not far to look for the reason of this. The stream itself is the drainage of a large lake and just before it drops into lake Superior it expands into a series of small lakes, so that the sediment which it carries over the rapids at Nipigon bridge is exceedingly small in amount, and the water appears to be perfectly colorless. Just below the rapids, however, the eddy of the stream is undermining a high embankment of sand and gravel and this affords sufficient material for the silting up of the small bay or inlet of Nipigon bay which forms the last couple of miles of the stream's course.

*The Delta of Gravel River.*—The Gravel river is bringing to the north shore of Nipigon bay a copious supply of gravel and the accumulation of this makes the delta of the stream a prominent feature of the present shore. The area of the delta which lies out beyond the general line of the shore is probably about a mile square. It is dissected by the stream and has a uniformly level apperance, any slope that it may have being exceedingly gentle. The surface of the delta, like that of the Mazokamah has the characteristic parallel ridge structure of the wave-built terrace, and the recent formation of the outermost of these ridges is very apparent.

*The Deltas of the Michipicoten and Pic Rivers.*—At the mouth of the Michipicoten there is an extensive delta accumulating resembling somewhat in its mode of development that of the Kaministiquia. The portion of the delta which is accessory to the present strand is due to the continuation of the processes which have been in operation through several higher stages of the lake. At the front of the delta successive beaches have been thrown up and in turn have been cut through by the stream. There is a similar delta at the mouth of the Pic river associated with which is a long sand beach of the present shore. Neither of these deltas was examined sufficiently carefully to warrant any farther statement regarding them. They would, however, doubtless well repay careful study.

*The Delta of Brulé River.*—The embayment of the coast into which the Brulé river discharges is filled with a great wave-built terrace, the material of which is partly a delta accumulation of the stream and partly due to the lodging of shore drift shed from the neighboring cliffs to the south. These cliffs and the rocks through which the stream is cutting are largely acid volcanic rocks of the nature of quartz-porphyries, easily susceptible of mechanical disintegration. As they have accumulated the fragments have been from time to time thrown up into storm beaches one in front of another till the embayment has been filled out nearly even with the general trend of the shore. It is one of the few cases of simplification of shore line by filling in on the Minnesota coast.

*Wave-Built Terrace at Grand Marais.*—The small wave-built terrace at the harbor of Grand Marais is the only one of note on the north shore of lake Superior which is not dependent upon a stream for its supply of beach material. A short distance to the northeast of the harbor is a sea-cliff of quartz-porphyry which is shedding angular fragments of rock from its face very rapidly. The cliff is vertical, and has receded between prominent points of more resistant rock till a distinct bay has been formed. At higher stages of the lake there has been a similar supply of the same material, though not all from the same cliff. The detritus thus accumulated has lodged at Grand Marais, and the formation of the harbor at that point is due to the extension lakeward of this embankment in the form of successive storm beaches, till the latter joined with the rocky island shore on which the lighthouse stands. This junction was effected by the running out of a spit from the shore till it met the island. The construction of the wave-built terrace was begun at somewhat higher stages of the lake than the present, and is doubtless still in progress, but the growth is on one side only of the original spit, there being no new supply of beach material within the harbor.

## MINOR FEATURES OF THE NORTH SHORE.

There remain to be noted as minor features of the north shore the forms known as *stacks, caves, clefts* and *pot-holes*, and these can be disposed of in a word. These features have been found only along the shore of the Keweenian province, and in all cases to a very limited extent and of exceptional occurrence. Stacks are only found where a portion of the shore, usually not more than a few hundred yards, is occupied by exceptionally soft material that is yielding rapidly to shore erosion to form a small bay or cove. The best and most characteristic stacks were observed between Baptism river and the Saw-teeth, where the rocks occupying adjoining portions of the shore are of very diverse character as regards their hardness and coherence.

Small caves a very few feet in diameter are found in the face of some of the cliffs. These are above the water line, and are not developed by the battery of shore drift against the face of the cliff, as there is no shore drift in sight; but are evidently caused primarily by some local weakness of the rock which enables simple wave action, assisted by the solvent power of the water, to wear out the cavities. Ordinary over-arched shore caves due to the battering of shore drift against the base of the cliffs are not found along the Minnesota coast, except at the Palisades, where some fine ones have been formed; and here the battering process is a small factor as compared with simple wave action acting on the infinitely jointed porphyry of the cliffs. These caves form magnificent archways, through which one may pass in a large row-boat with ease. [See Pl. XI., Fig. 1.] Ordinarily, however, the cliffs are so low that the incision made at their base is, owing to bedding and jointing planes, carried to the summit, and a distinct Λ-shaped cleft in the face of the cliff is the result. These clefts are numerous along the Minnesota shore, and there may be seen almost invariably lying on their sloping bottom the boulders and pebbles with which their sculpture is effected. There is a fine arch on the north side of Pigeon point wrought out of coarse gabbro.

Pot-holes are not commonly developed on lake shores. They are usually the products of stream action. On one part of the Minnesota shore, however, they are distinctly the product of wave action, and may be observed in process of formation. The place where they were observed is on the shore about two miles east of the mouth of the Temperance river. Here the shore is occupied by an amygdaloidal lava of uneven texture, which forms a shelving lakeward sloping platform. In this platform are numerous pot-holes, the deepest having a depth of about four feet and a diameter at the mouth of about three feet. In the bottom of the pot, unless it is very shallow or has been breached, there are always one or more hard erratic boulders, which do the work of grinding out the hole when set in motion by the waves pouring over the surface of the platform. The holes are not as symmetrical as hose formed by stream action, but there is no essential difference between them and the latter. It is to be noted that the rocks which are here susceptible of having pot-holes developed in them by wave action also afford in the canon of the Temperance river the finest, though not the largest, pot-holes to be seen in any of the streams of this coast. The canon of the river is formed by a systematic series of deep pot-holes which have breached into one another, giving the walls of the canon a concavely scalloped form.

Similar shore pot-holes are referred to by Agassiz as occurring at cape Choyye.

## COASTAL CONTOURS.

### THE PRESENT SHORE CONTOUR.

Of the various elements of a coastal topography the shore contour is the most constant and therefore perhaps the most essential and important. Other topographic elements may shrink into comparative insignificance and some of them may vanish entirely or may never be developed, but the shore line is always present. Like some other phenomena that belong to the category of the "ever present" it is apt to be overlooked among the factors in the total effect which constitutes the topography of a coast. The variation in the character of a shore line is a variation in quantity—in the length of the line. In quality it is practically unvarying, there being no attributes of excellence or imperfection by which we can qualify a description of it. Its shape or form of curve may be regarded roughly as a function of its length, being simple or intricate in proportion to the extent of time which traverses a circle of a given diameter and passes through to the center. The inconstancy of direction of the shore renders the possible variation of the form of the contour practically infinite. Thus the most constant feature of a coastal topography may be the most inconstant in form. But notwithstanding this variability there is usually a certain broad character peculiar to the contour of any shore developed under uniform geological conditions which, though difficult of precise description, may be distinguished readily from that of an adjoining shore developed under different geological conditions. This statement would probably be difficult to substantiate in the case of very mature shores, but it is probably only in exceptional cases where the shore of a large lake is uniformly mature, and the degree of maturity is largely dependent upon geological conditions.

When we consider the form of the shore contour of the north side of lake Superior in its relation to our four geological provinces, we are at once struck by the pronounced character peculiar to each province. In none of the other topographic features of the coast is there a more definite and unmistakable dependence upon strictly geological conditions. The moment we pass from one province to another so soon do we pass from one kind of shore contour to another. This contrast of the character of the shore contour can best be appreciated by an inspection of a map of the lake. But as maps of lake Superior on a suitable scale for such a comparison are not common, certain portions of the shore are here reproduced to illustrate the character of this feature in the different provinces. [See Figs. 1, 2 and 3.] And here it is well to recall the fact that the *apparent* simplicity of a shore line as interpreted from a map is in a measure dependent upon the scale of the map. Of the two shores both mapped as simple lines one may be serrate in minute detail while the other may be quite as simple as represented.

*Shore Contour of the Keweenian Province.*—The shore contour of the Minnesota coast from Duluth to Grand Portage is on the whole a remarkably simple line. It has the form of a slack bow concave to the lake. Projecting headlands and deep bays are entirely absent. Such salients and re-entrants as are worthy of note are obtuse in form and do not appreciably add to the length of the shore line. Yet in minute detail the line is frequently sharply jagged and serrate; and there is a marked absence of those sweeping sinuous curves which characterize mature shores. Shore erosion is active in the production of coves and the whole tendency of development appears to be, in this adolescent stage of the shore, the reverse of simplification. The present stage of the lake found the shore without indentations and a vigorous beginning has been made in the work of evolving them and in effecting a more intricate form of shore contour. But it is scarcely more than a beginning. The notches, clefts, and coves of the shore can only be rendered appreciable on a very large scale map and do not affect the general statement of the simplicity of the shore line considered as a whole. The shore contour of the Keweenian in the vicinity of Black bay and between that and Nipigon bay is very different from that of the Minnesota coast, and the reasons for the difference are not fully understood as the Canadian distribution of the Keweenian has not been carefully examined. This much is known, however, that in the latter district the shore contour is intricate, and is further complicated by [illegible] of great numbers of islands lying off shore in a [illegible] belt. The

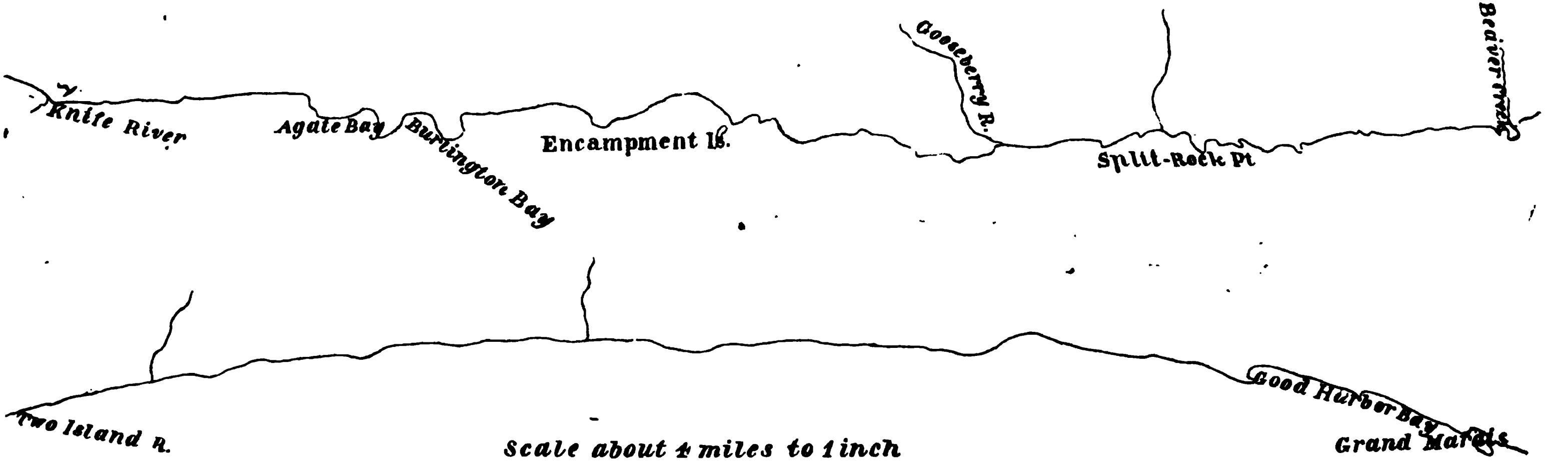

Fig. 1. Examples of the most complex and the simplest shore contours of the Keewenian Province along the Minnesota Coast.

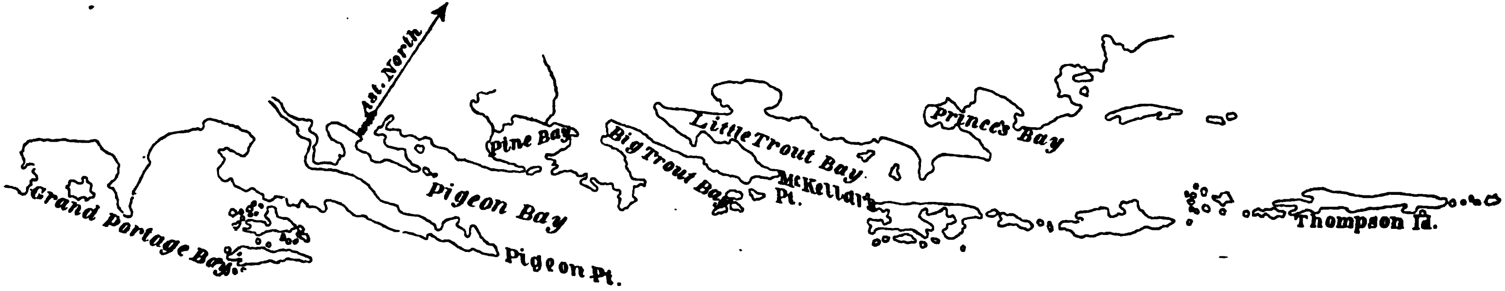

Fig. 2. Shore contour of the Animikie Province. Scale four miles to an inch.

conditions differ from those on the Minnesota coast in the presence of a greater mixture of clastic rocks among the volcanic and in the greater abundance of dykes. These differences do not seem, however, to fully account for the great contrast in the topography of the two Keweenian areas; and the suggestion is strengthened, that the simplicity of the Minnesota coast is due to the fact that primarily it is a fault scarp.

*Shore Contour of the Animikie Province.*—The general trend of the shore along the front of the Animikie province is not a simple line. Deep narrow bays and prominent sharp headlands prevail, and the length of the shore line is large in proportion to the extent of the coast. The sculpture which gave rise to these bays and points is pre-lacustrine and the tendency of the shore action is, in contrast to that noted on the shore of the Keweenian province, towards simplification. The tendency in this direction is, however, not strongly marked on account of the resistant character of the extremities of the promontories which have not yet been appreciably truncated at the line of the present stage of the lake. See Fig. 2. The tendency is chiefly manifest in the filling up of the heads of the bays. While the shore contour of the Animikie province is in strong contrast to that of the Keweenian by reason of these large salients and re-entrants there is also a radical difference in the minute detail of the shore contour in the intervals between the points and along those portions of the shore which are exempt from bays. There is very little of the sharp local notching and clefting of the shore line where the shore is rocky and none of it where the shore is occupied by shingle. Thus the shore contour of the Animikie province is intricate in its general features but simple in its minute details; while that of the Keweenian is simple in its general features and serrate in its minute detail. The conditions governing the local trend of the bays and points along the Animikie front is easily recognizable and there is a prevailing parallelism in these features.

*Shore Contour of the Archæan Province.*—The shore contour of the Archæan province is exceedingly intricate in detail. If the shore were represented on a map of a scale sufficiently small to obliterate the detail, so that it would express merely the mean trend of the coast, it would be indicated by a fairly simple, obtusely zigzag line extending from Nipigon to Sault Ste. Marie. In this general and varying trend there may be recognized two degrees of detail: (1) Wide-mouthed bays and broad or obtusely rounded headlands which indent the mean trend of the shore to the extent.

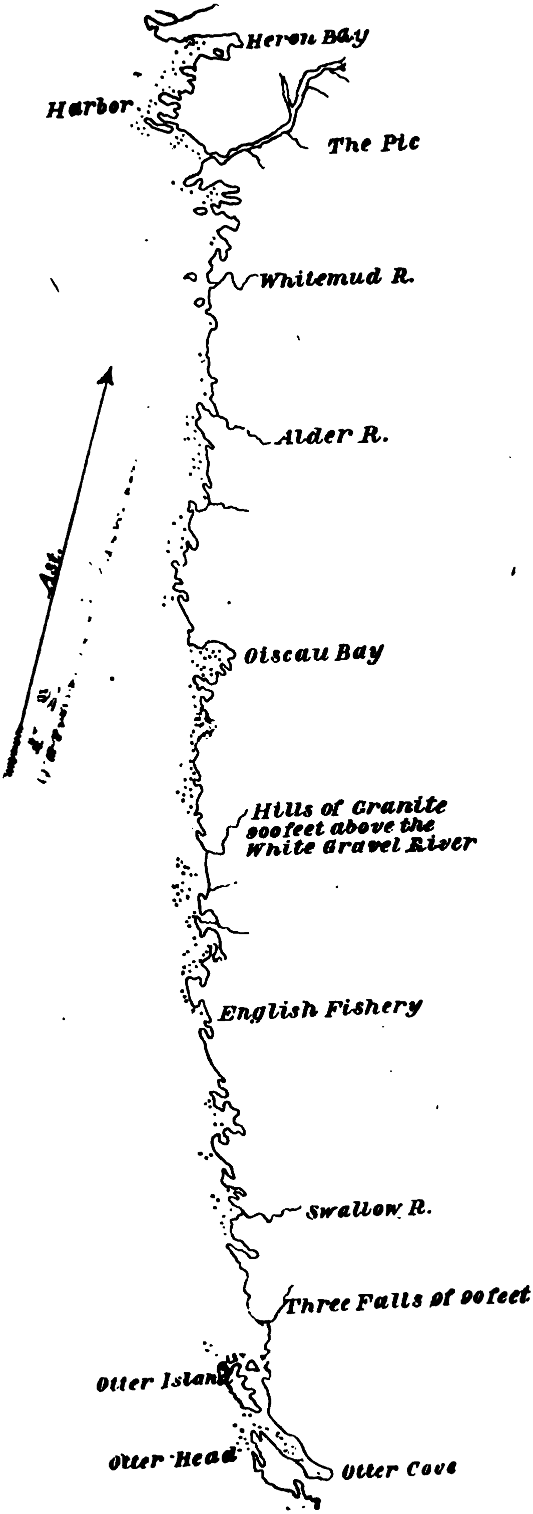

Fig. 3. The shore contour of the Archæan Province. Scale five and one-third miles to an inch.

of from two to five miles, and (2) a much more elaborate indentation of a minor kind, which is the most characteristic feature of the shore of the Archæan. It is in this minor indentation that the shore contour is most intricate. It gives the shore, when mapped on an adequate scale a distinct *suture*-like appearance, to understand which it is necessary to remember that the shore line is produced by the submergence of a hummocky or mammilated slope. The land and water seem to interlock much as two bones of a skull do. As regards the major indentations of the shore the controlling condition of their evolution, under processes of pre-lacustrine erosion, has doubtless been the variation in the petrographical character of the formations along the line of the present coast. The green stones of the Ontarian system of rocks seem to have been more resistant than the granite and gneiss of the Laurentian and have in some cases given rise to headlands. In other cases one portion of the Laurentian was probably less susceptible to secular decay than another and so stands out as a promontory. The law controlling the evolution of the form of the minor indentations is not apparent. It is the same as that governing the forms of the *roches moutonnees* and the hummocks. In neither the major nor the minor indentations is there any semblance of parallelism, the forms and directions of the bays and points being exceedingly diverse and irregular. In spite of the excessive intricacy of detail of the shore contour, the indentations of this line are very rarely sharply angular but are rather rounded, being practically the local partial contours of the hummocks and lumpy rock masses of the coastal slope. The present tendency of shore action is towards the simplification of the shore contour, but as pointed out in another place, it is only feebly effective on account of the smooth obdurate character of the rocky points and the consequent scarcity of shore drift to fill in the bays. A characteristic feature of the Archæan coast and one which is supplementary to the minor indentation of its shore line is the presence of the fringe of rocky islets lying close in to shore. These of course are but the summits of hummocks and *roches moutonnees* which have been so far submerged as to be completely encircled by water. See Fig. 3.

*Shore contour of the Potsdam Province.*—The extent of the Potsdam province, on the north side of lake Superior, is so limited and so broken up into isolated patches that any generalization as to the character of its shore contour would be of questionable value, were it not that the same province has an extensive distribution on the adjoining south side of the lake, under similar conditions. The shore contour of the province is that of a mature shore. In detail it presents sweeping sinuous curves, and the few angularities are apparently due to the development of spits, or to the local accumulation of coarse glacial debris, in shallow water. The simplification of the shore line is far advanced, although there are some small bays without apparent bars across their entrance. Such bays are, however, very shallow. The general trend of the shore line is irregular, and has no dominant direction for the reason that the geological province is geographically, if not geologically made up of outliers of the more extensive formation of the same rocks on the south side of the lake.

## THE HILL CONTOURS.

Inasmuch as the topography of the coast is, in its broad features, essentially pre-lacustrine, the shore contour is only a special case of the hill contours; and our consideration of this special case anticipates, in some degree, an account of the more general contours of the coastal slope. These contours, as they would appear on a topographic map, are, quite as much as the shore contour, characteristic for each province. In the Keweenian province the hill contours, inland from the brink of the shore cliffs, are prevailingly long sweeping lines, usually uniformly spaced for a constant vertical interval. On a map closed curves, indicating isolated hills, would not be numerous, and only in a very few cases, such as at Carlton Peak, would they approximate a circular form. These hill contours would not, however, have the same constancy of trend as that evinced by the shore contour of the present strand. This comparison of the shore contour with the hill contours brings into prominence the fact that at none of the higher stages of the lake has the shore of the Keweenian province been so simple a line as it presents for the existing strand. Many sinuousities, bays and headlands characterized the shores of the earlier stages of lake Superior along this portion of the coast.

In the Animikie province the hill contours would for the most part show a prevailing parallelism with the shore contour, but with a greater amount of indentation. The prevalence of mesa scarps and dykes would, as compared with the Keweenian coast, necessitate a great crowding together of contour lines; while on the tops of the mesas the same vertical intervals would be widely spaced. In their trend, also, these contours would show sudden bends and sharp angularity, features which contrast with the gentler curves of the Keweenian province. Closed curves would be even more exceptional than in the Keweenian, but would occur in the case of isolated mesas similar to Pie island.

In the Archæan province the hill contours are very distinct from those of either the Keweenian or Animikie provinces. Whatever general parallelism they may have with the present shore is obscured by their great irregularity. The hummocky character of the country would give rise to a great abundance of closed curves in contours of small interval, and these would constantly approximate circular and oval forms. The majority of the contour lines would be exceedingly serpentine in character, or suture-like as in the case of the present shore. For the same interval they would not be so uniformly spaced as in the Keweenian province, nor would they ever be so unequally spaced as in the mesas of the Animikie.

In the Potsdam province the contours, even of very small interval, would, on a map, be few in number, widely spaced, and sinuously straggling as is usual in nearly flat tracts.

## COASTAL PROFILES.

Those elements of the coastal topography which are best expressed by profiles evince, as has been already remarked, a very striking dependence on geological conditions; and the profiles in each province are characteristic for it to a remarkable degree. The petrographical and structural features of the four provinces find very distinct expression in the form of the coastal slope.

The possibilities of variation in a topographic profile are seemingly great. As a matter of fact, however, there is but a limited number of *types* of profile actually met with in the inequalities of the earth's surface; and nothing would startle the geological eye more than to meet with certain profiles which are mathematically possible, and easily conceivable, but which are not developed by geological agencies.

It is not proposed here to enter upon a discussion of these types of profile in general, but a few may be enumerated as of dominant occurrence in lake Superior topography. For the sake of convenience the writer will take the liberty of specifying those different types of profile by definite names, some of which are in common use.

*The Dip Profile*—in which the slope is definitely conditioned by the dip of inclined strata. This profile is common as a portion of anticlinal, synclinal or monoclinal structures, and is of frequent occurrence where the full structure is not revealed. It also constitutes portions of the full profile of many tilted orographic blocks.

*The Flat Profile*—in which the vertical element is very insignificant; common in undisturbed horizontal strata, the upper beds of which are not much above the local base level of erosion. This would of course include base level plains of deposition. The same profile may also be found in base level plains of erosion.

*The Mesa Profile*—in which the vertical and horizontal elements are nearly equally effective and are manifest in the profile as actual vertical and horizontal lines respectively. Most common where table lands are wholly or partially circumscribed by cliffs of differential degradation.

*The Strike Profile*—the outline of a section of inclined strata taken parallel to the strike of the rocks. Theoretically the profile is characterized by a dominant horizontal line. In reality the horizontal line is usually interrupted and indented by features due to uneven erosion.

*The River Trench Profile*—the profile across a line of drainage, usually representing a distinct trench, the form of which varies according as the drainage is new or old—juvenile or senile—from the sharp V-shape of a mountain cañon to the broad flat-bottomed valleys of a base-leveled plain. On lake Superior the latter of these extremes is never found. With reference to their present base level all the streams are young and are actively cutting trenches. But they are mostly small and the cañons, with one or two exceptions, such as that of the Pigeon, below the falls, and the Kaministiquia, below the falls, are not imposing.

*The Precipice Profile*—in which the vertical element is greatly in excess of the horizontal, and which lacks the flat top of the mesa. The forms which give this profile may be developed in a variety of ways. It may be part of the fallen but not wholly revealed profile of many sea-cliffs. It is common in the forms resulting from stream erosion and along fault lines.

*The Dyke Profile*—usually the profile of a sharp ridge with a definite approximation to verticality on both sides, resembling two precipice profiles back to back. Frequently on lake Superior the vertical aspect of the profile is diminished by the adherence to the sides of the dyke of indurated portions of the country rock intersected by it.

*The Hummock Profile*—characteristic of the forms resulting from the gradual decay of massive crystalline rocks; very common in Archæan terranes where this character of surface now prevails, and also prevailed prior to the deposition of the earliest Palæozoic strata, although evidence of secular decay of the pre-Palæozoic surface is exceedingly meagre. Rotundity is the chief characteristic of the hummocks so that *convex* curves mark their profile. The arrangement of the hummocks with reference to one another is very irregular so that no two neighboring profiles exactly agree, although the general characteristic is never lost.

*The Talus Profile*—the slope of repose of angular fragments of rock; common on certain parts of the coast of lake Superior but always subordinate to more important profiles, usually that of the mesa; never a dominant profile as in the case of cinder cones.

All of these profiles may be observed on the coast of the north side of lake Superior. Other types also exist, but it is believed that they are of minor importance for the purpose of this discussion, which does not pretend to be exhaustive. Some of these types may exist alone or in combination with others; while some exist only in combination. They may be regarded as *primary* profiles or of prime importance in giving character to the topography of the coast, being the results of sculpture, under various geological conditions, of the beveled edge of the rocky plateau which limits the lake basin.

These primary profiles are frequently, however, locally modified by the imposition upon them of secondary profiles due to former lacustrine action. These secondary or modifying profiles are those of the various shore embankments and terraces which have been developed at stages of the lake higher than the present. And it is these modifications of the coastal topography to which special attention is directed in the sequel. But first a brief comparison will be instituted between the primary profile of the different geological provinces.

Independently of their topographic character the profiles of a coast may be classified according to the direction in which they are taken with reference to the trend of the coast as, (1) the parallel profile and (2) the transverse profile. The topographic type which these two directions of profile exhibit in the different geological provinces will now be briefly stated.

## THE PARALLEL PROFILE.

*The Keweenian Province.*—The parallel profile of the Keweenian province is characterized by the dominance of those special types of profile which have been designated the "strike profile," modified by the "river trench profile." Generally speaking, the strike of the rocks is parallel to the shore, and a general section through the coast close to the shore line and parallel to it would show a long approximately horizontal line notched by stream trenches and the deeper coves of the shore. The vertical distance between the level of the lake and the line of the profile would be comparatively small, but would increase in proportion as the line of section was taken more and more remote from the shore.

*The Animikie Province.*—In this province a section of the coast parallel to the mean trend of the shore, or roughly coincident with it, would show in the western part a prevailing series of "dyke profiles," and in the more eastern part very pronounced "mesa profiles." The dykes are on a grand scale, and as they form the axes of several of the long points which condition the bays, they appear to advantage in a section across these bays, though cutting them obliquely. Many of these great dykes, though rising in precipitous ridges, some nearly a thousand feet in elevation, have considerable masses of the adjacent country rock adhering to their sides, while others have lost this and rise shear from the water. This prominent dyke topography is practically absent in the Keweenian, except at a few localities, of which the vicinity of the Saw-teeth is the most notable. The horizontal line of the mesa profiles differs from the same line in the strike profiles of the Keweenian in the greater vertical interval between it and the lake level, and also in the fact that this interval is practically constant, however remote inland the section may be taken. A marked characteristic of the coast of the Animikie province, also which appears in this profile, is the talus profile, subsidiary to that of the mesas. In none of the other provinces do these talus slopes appear.

*The Archæan Province.*—The characteristic parallel profile of the coast of the Archæan province is that of the hummock, and does not differ essentially from the transverse profile given in generalized form in Fig. 6, except, that in a section coinciding with the mean trend of the shore, it would be broken by intervening stretches of water.

*The Potsdam Province.*—In this province the parallel profile is that designated as the "flat profile," and is somewhat similar to the strike profile of the Keweenian. It would differ from the latter in being closer to the line representing the lake level and in being more nearly horizontal, or so lowly arched as to be sensibly horizontal, and would be free usually from the interruptions due to the stream trenches and sharp coves of the Minnesota coast.

### THE TRANSVERSE PROFILE.

*The Keweenian Province.*—If one leaves out of consideration the hummocky gabbro hills of Duluth, which are of limited extent, the transverse profile of the Minnesota coast is characteristically the "dip profile" in combination with which at the water's edge is a "precipice profile," where the slope of the coast breaks away shear. There is a uniform and constant lakeward dip of the bedded volcanic flows and injected sheets of which the series is composed, and the slope of the coast is clearly conditioned by this dip. At a few places along the coast the underlying basement upon which the Keweenian rests emerges in the beautifully rounded hummocks so characteristic of the Archæan terraces, but these are so limited in extent that they do not affect the character of the profile except in one case. This is at Carlton peak, where, at a distance of something less than two miles from shore, a huge dome of the underlying basement rock projects through Keweenian strata and gives its character to a portion of the profile. To the southwest of Carlton peak, also, a heavy sheet of coarse gabbro, several hundred feet in thickness, probably the remnant of a great intruded sill, rests upon the Keweenian flows and has a dip conformable with them, giving the appearance of a tilted mesa with a great scarp facing the northwest, and a less pronounced mesa edge facing the lake. Other localities where the characteristic "dip profile" is notably deviated from are, in the vicinity of the Saw-teeth, where there are important irruptive masses, intersecting the Keweenian; at Farquhar's knob, a ridge whose structure has not been investigated; at Beaver bay, where there is some topography of the mesa type; and at Grand Marais where, to the west of the harbor there is also a mesa ridge and to the northeast a moranic accumulation. The precipitous termination of the coastal slope, near the shore varies somewhat in character. Where the rock is a single mass from the water's edge to the top of thecliff, it is usually almost or quite vertical, as at the Palisades where the cliffs have their maxium elevation of 210 feet. Where the cliff is composed of different strata it is frequently step-like in character.

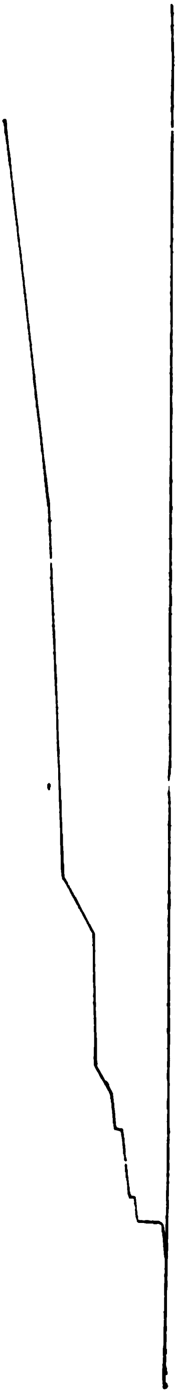

Fig. 4. Transverse profile of the Keweenian Province modified by the presence of two terraces.

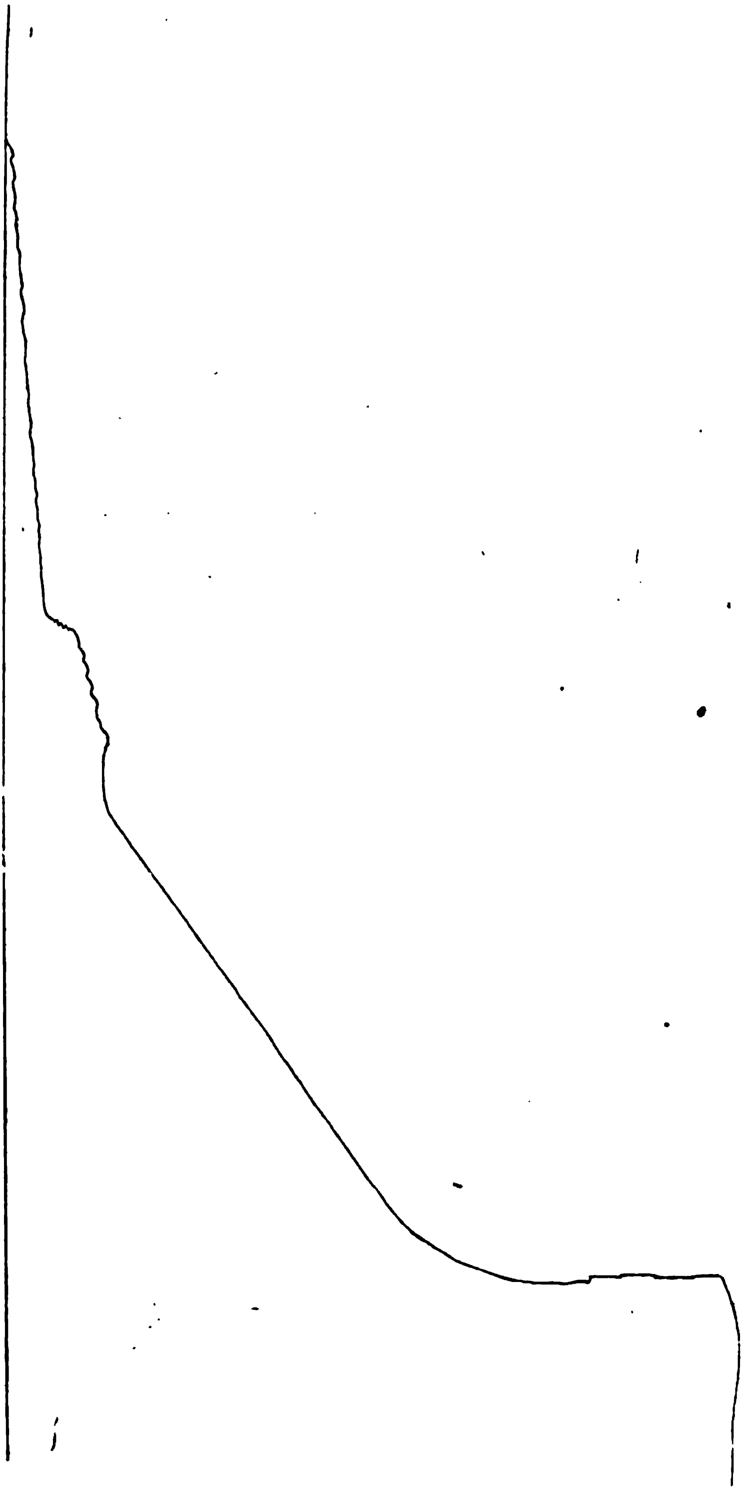

Fig. 5. Transverse profile of Animikie Province modified by a terrace and several beaches.

The transverse profile of the Minnesota coast is frequently modified by the presence of embankments and terraces of the ancient strands of the lake and it is probable that were the timber removed this modification would prove to be much more extensive and important than can at present be recognized.

*The Animikie Province.*—The transverse profile of the coast of the Animikie province is characteristically that of the mesa, usually with the subsidiary talus profile, but sometimes without it. The dyke profile is, however, not uncommon in the same part of the coast where it appears in the parallel profile. In the valley of the Kaministiquia the transverse profile is exceptional, as will be understood from what has been said of the development of the delta of that stream in a former part of this paper. At Port Arthur a trap sheet, such as usually forms the cap of the mesas, dips towards the lake and passes beneath it, and there is other evidence of local disturbance so that the profile here is abnormal. It is, however, more effectively modified here by the embankments of the former strands of the lake than is usually the case. Towards the head of Thunder bay the transverse profile crosses both the Animikie formations and the underlying Archæan, which emerges from beneath it, and the profile is correspondingly complex.

*The Archæan Province.*—Throughout the coast of the Archæan province the hummock profile prevails in sections transverse to the coast as in those parallel to it. The exceptions are few and are quite local. Where the coast is coincident with the strike of the schistose rocks, however, the hummock profile is combined sometimes with the precipice profile, and also at some few localities where sea-cliffs have been developed in massive rocks. Two of the exceptions to the general hummock profile are of special interest. In the profile of the coast to the east of Rossport there are places where a very distinct precipice appears with a shelf at its base, not immediately at the shore, but at some little distance from it. Resting at the base of the cliff are small outliers of the Keweenian lava flows, in place, showing clearly that the cliff is pre-Keweenian in date. Other portions of the hummocky slope of the north coast of the lake have small outliers of such volcanic rocks and also of Keweenian sedimentary rocks which locally modify the profile to a minor extent.

The second exception is also of exceptional occurrence. It occurs where the line of profile crosses some of the numerous trap dykes which intersect the Archæan of this coast. Very frequently these dykes have disintegrated much more rapidly than the adjoining country rock so that the spaces formerly occupied by them are now

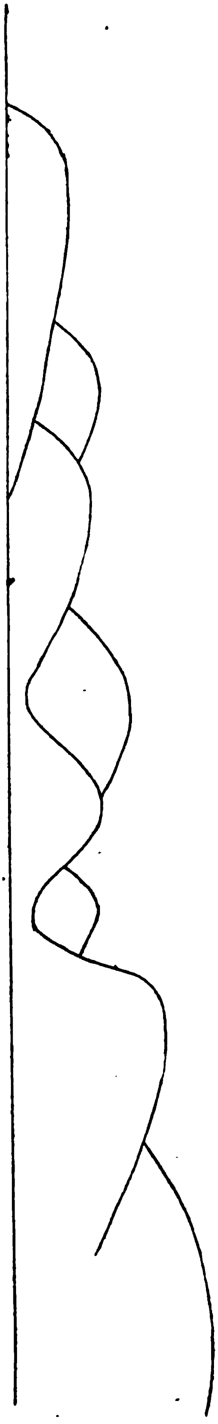

Fig. 6. Generalized transverse profile of Archæan Province.

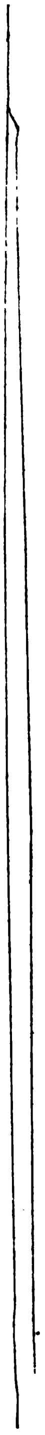

Fig. 7. Transverse profile of Potsdam Province.

The transverse profile of the Minnesota coast is frequently modified by the presence of embankments and terraces of the ancient strands of the lake and it is probable that were the timber removed this modification would prove to be much more extensive and important than can at present be recognized.

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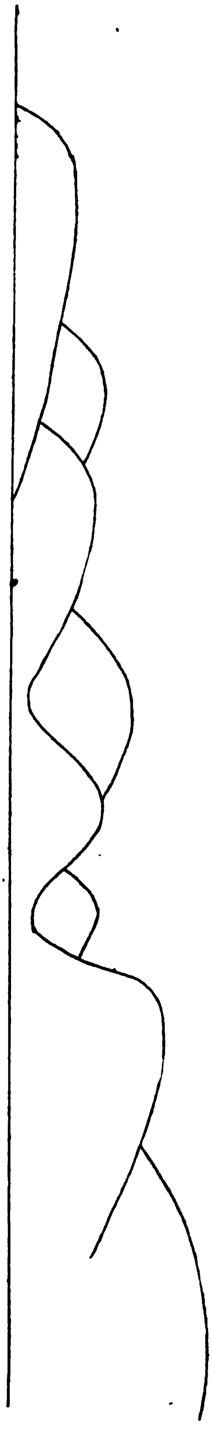

Fig. 6. Generalized transverse profile of Archæan Province.

Fig. 7. Transverse profile of Potsdam Province.

tion of shore features developed at the various stages from which the actual water levels may be inferred, within certain considerable limits of error.

Before discussing the data obtained by the inquiry or formulating any generalizations it will be well to first become familiar with our facts, and to this end a brief descriptive account is given of the various series of strand lines observed on the coast. The results of the levelling also are summarized in the table at the close of the descriptive notes. In these notes the word series and the number attached to it has the same significance as in the table. The Roman numerals also refer to the table. The table is expressive of a correlation which is discussed in the pages which follow it.

## DESCRIPTIVE NOTES.

*Series 1.—Duluth West.*—On the hills of the city of Duluth a very clear and excellent registration of some of the higher stages of the lake may be observed. The city, as is well known, is being built upon the steep lakeward slope of a massive, rounded range of coarsely crystalline gabbro, which within the city limits rises to an elevation of probably 800 feet above the present level of the lake. On the upper portion of this slope the topography is such that it has been found a convenient and easy matter to construct, as part of the general embellishment of the city, a magnificent carriage drive around the brow of the hill. This carriage drive follows a contour line at an average elevation of perhaps 470 feet, and is known as the Lake View terrace.

It requires but a cursory inspection to see that the particular phase of the topography which has suggested and made easy the construction of this Lake View terrace is due to the imposing upon the steep and rocky hill-side of a feature which has been developed along a former shore line of the lake. This feature consists of a pronounced natural terrace or shelf facing the open lake. It varies considerably in width, being narrow where it rounds the shoulders of the hills and widening out very much in the bays and recesses. It has a gentle but constant slope lakeward, and ends rather abruptly on its outer edge, dropping away into the general steep slope of the hill. The back of the terrace is limited usually by the rounded glaciated forms which characterize the upper portion of the gabbro mass. These rounded forms at the back of the terrace are in places replaced, however, by vertical cliffs of gabbro with large blocks which have fallen from its face [illegible] about the rear of the terrace and partly imbedded in [illegible] face of rock

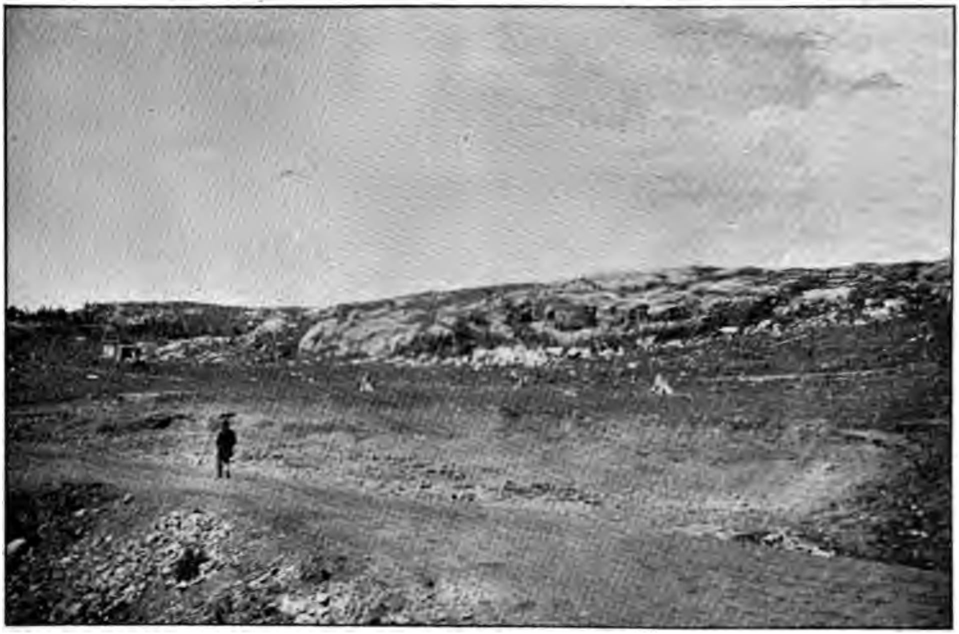

FIG. 1. LAKE TERRACE WITH SEA-CLIFFS IN BACK GROUND, END OF NINTH AVE. W., DULUTH. PARTIALLY MASKED BY SUBSEQUENT WASH AT THE RIGHT. (P. 233.)

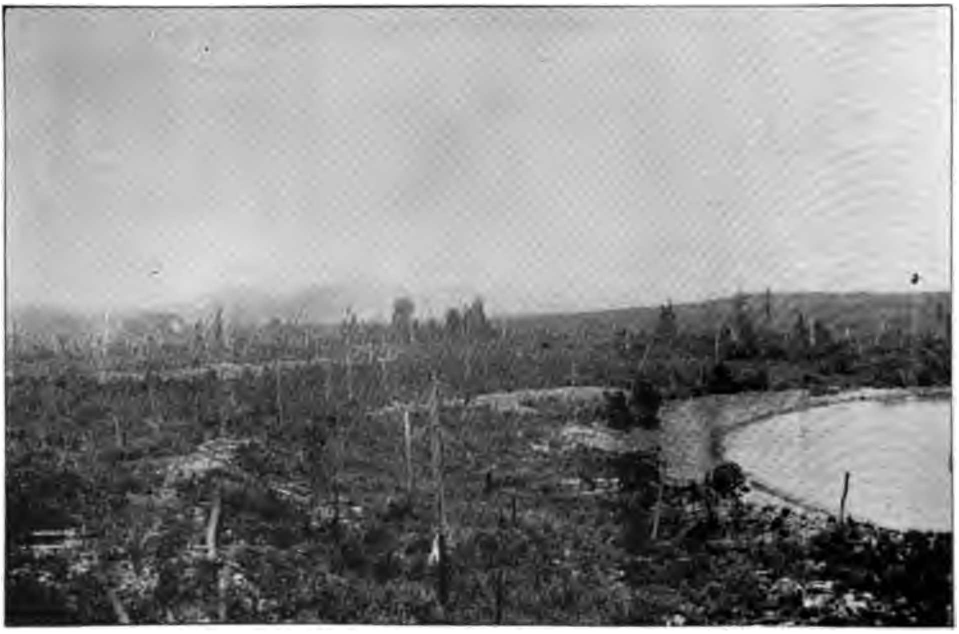

FIG. 2. BOULDER BEACHES, HORSESHOE BAY. (P. 247.)

with its talus of angular blocks represents undoubtedly a "sea-cliff" and is like the terrace a product of shore action. An example of such a sea-cliff may be seen near the upper end of Ninth Ave. West. [See Pl. VIII, Fig. 1.]

The material of which the terrace is built consists of surf-rolled boulders, pebbles, gravel and sand. The arrangement of this material is well seen in the cuts which have been made at a few points in the construction of the drive. In the cut at the upper end of Ninth Ave. W. about 150 feet in front of the sea-cliff just mentioned, the terrace has been sunk into so as to afford a vertical section of 9 feet. The lower 6 feet of this section show sharply bedded gravel and sand with occassional boulders up to one foot in diameter. [See Pl. X, Fig. 2.] The upper 3 feet of the section although composed of the same materials is not distinctly bedded, but this obscuration of the stratification may be due to the action of vegetation. The strata intersect the vertical plane of the section usually in quite horizontal lines. At the south end of the cut, however, oblique bedding of alternating wedges of gravel and sand is well seen, the dip of these beds being 25 degrees and less.

The relations of the various factors of the topography at the head of Ninth Ave. W. is illustrated in the diagrammatic section.

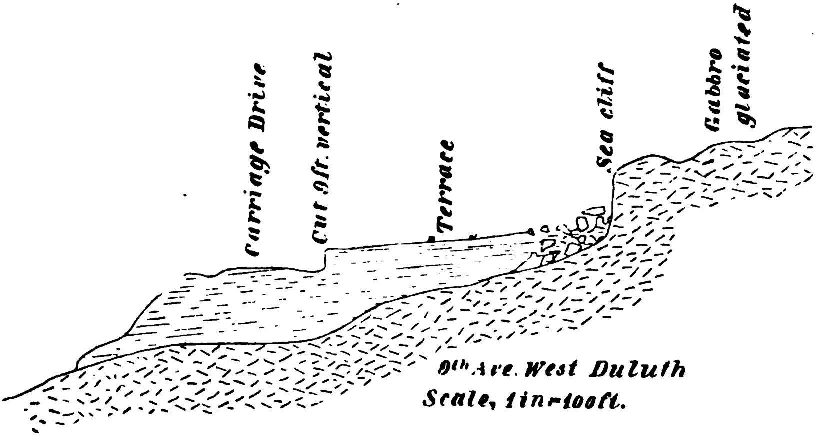

Fig. 8. Section at the head of Ninth Ave. W., Duluth. Elevation of terrace, 476 feet.

The rear of the terrace in front of the sea cliff was found to be 475.9 feet above the lake (XXIX). The structure of the terrace shows that while primarily it is a wave-cut feature, the cut shelf of rock and the slope below it is covered with current-sorted material which was probably brought down by minor drainage.

Evidence of shore lines at lower levels in the western part of Duluth were not satisfactorily observed, although they will probably be found if looked for on the slopes between Duluth and Fond du Lac.

At a higher level, however, there is a great beach which spans an embayment in the hill front and stretches continuously between the two shoulders of rock which are at the head of Sixth and Eighth Aves. W. respectively. The Seventh avenue inclined railway, which was under construction at the time the examination was made, terminates on this beach, the crest of which was found to have an elevation of 534 feet (XXXI). The presence of the beach is clearly revealed by the topography which it imposes upon the hillside. The contrast with the unaffected portions of the hill is striking. The horizontality of the beach crest is the feature which first attracts attention, the longitudinal profile of the beach with the rock on either side being not unlike that of the upper half of a dumb-bell, thus ⌒——⌒. The transverse profile shows the characteristic undulatory front slope of shingle beaches, the descent being by a succession of rounded steps. The same profile shows also a well marked lagoon hollow behind the beach. The ground plane shows that this lagoon hollow is entirely inclosed by the straight beach in front and by the rocky slopes of the hill on the sides and in the rear, so that the contour of its rim is roughly of the form of the letter D.

At the south end the beach has been quarried for road ballast and there the material which enters into its composition and the arrangement of the same is readily observable. The material consists chiefly of pebbles and boulders which range in size from two to six inches and have a prevailingly rounded form. There are a few large boulders up to two feet in diameter and a good deal of finer gravel. Stratification is not discernible in the mass of the beach and the pebbles and boulders are piled up in the irregular fashion so well exhibited by the living beaches of the lake. There was no longitudinal section which would permit of an observation as to the sorting of the material according to its relative coarseness. In the upper part of the beach there is some fine gravel and sand which shows a stratiform arrangement, but this is probably due to wash from the lagoon, since such drainage would doubtless have kept a way open for itself through the beach.

The undulatory front slope of the beach extends from its crest at an elevation of 534 feet down to the rear of the terrace already described at an elevation of 475.9 feet, and the relations seem to warrant the inference that the higher strand line is the older and that the water subsided by stages till it arrived at the one marked by the Lake View terrace, where it remained constant for a sufficient length of time to evolve the striking feature of the togography, the terrace being in fact cut into the slope of the older and higher beach.

*Series 2.—Duluth, Tenth Ave. East.*—Near the head of Tenth Ave. East, three distinctly marked strand lines are recognizable. The highest of these is a wave-built terrace of pebbles and boulders resting on a rocky slope and facing the open lake. Careful levelling established its elevation at 534 8 feet (XXXI) which agrees within a foot with the altitude established by an entirely independent line of levels for the beach at the head of Seventh Ave. West. From this elevation down to an altitude of 436.2 feet, or in round numbers a vertical distance of 100 feet, there is a continuous bank of beach material comprising boulders, gravel and coarse sand, lying upon the slope of the hill. On the front of this great embankment there is a level terrace, which, while not very broad, is persistent and on being traced southward is found to abut directly against the rocky slope at a place where the upper terrace is wanting. This second terrace was found to have at the rear an elevation of 473 feet (XXIX) which again agrees very closely with the figures obtained for the rear of the Lake View terrace in West Duluth. The structure of the upper terrace is not revealed by any section; but below the 473 foot terrace there have been a number of excavations for road ballast and in these it is seen that this lower part of the gravel bank is distinctly stratified with a dip in the direction of the slope of the hill, but at a much less angle. There is a small ravine to the left of the higher terrace and there is little doubt that the stream which flowed down this ravine supplied the material of which the whole of the 100 foot bank is constructed; and the development of the two terraces and the stratiform structure seen below the second one is probably explained by the following considerations:—

The bedrock of the ravine is much lower than the upper terrace (XXXI), and was so when the lake stood at the level at which the terrace was built. The ravine after becoming itself filled with detritus to the level of the lake would supply the material for the terrace, and besides this there would be much which would be carried down to the subaqueous slope and arranged by the varying currents into strata. As the level of the lake subsided the ravine would be cleaned out and its accumulations spread out on still lower slopes also in bedded fashion. In this way the 100 foot bank of gravel, etc., stratified in its lower part, would have been accumulated. The strand line XXIX represents a stage in the recession of the water, at which, as in West Duluth, a second terrace was imposed upon the slope of the growing bank, partially cutting into the flanks of the upper terrace.

At the foot of the rather steeply inclined 100 foot bank of beach material, the slope suddenly changes and flattens out into a broad, gently inclined terrace in which no rock in place is seen. The rear of the terrace was found to have an altitude of 436.2 feet (XXVII). Its surface is composed of a dark earth in which are embedded scattered boulders, and it is covered with grass or timber so that its substructure is not apparent. On following the rear of this terrace northward beyond the gravel pits, it is found to abut against the *roches moutonnees* of the hill-side without the intervention of the gravel. The age of this terrace relatively to the gravel terraces above it is doubtful. It is uncertain whether the gravel bank rests upon the rear of this terrace or whether the terrace is imposed upon the lower flanks of the gravel bank. Owing to the absence of natural sections no ready answer presented itself to this question, and time was not taken to investigate it. It is possibly an older terrace, but evidence of this supposition is lacking.

*Series 3.—Hardy's Schoolhouse.*—Near the eastern limits of Duluth, in the vicinity of Hardy's schoolhouse, there is a magnificent illustration of that phase of topography which is due to the development of a bar beach and delta deposit at the mouth of a valley, which has been the channel of a stream flowing into a lake at a level now abandoned. The altitude of the crest of the barrier beach was found to be 509.5 feet (XXX) above the lake. Northward from it there extends a forest-clad, rock-walled valley about a mile wide at the mouth where spanned by the barrier beach. About the mouth of the valley are several isolated rocky hills which evidently formed islands in the lake when it stood at this high level. They rise from out of the beach formation or from the flat-lying delta deposits farther out which represents the shoals of the old lake bottom. The crest of the beach has a curvilinear form and extends in a southwesterly direction from the rocky knob at the schoolhouse, which stands at its northeast extremity, to the rocky hills which rise at the back of the city. In a general way it seems concave towards the valley, but it is by no means a simple ridge. It has a very extensive aerial distribution, and while on the side it presents sections, as along the line of the electric tramway, which are simple lowly-arched ridges of beach material, towards the middle

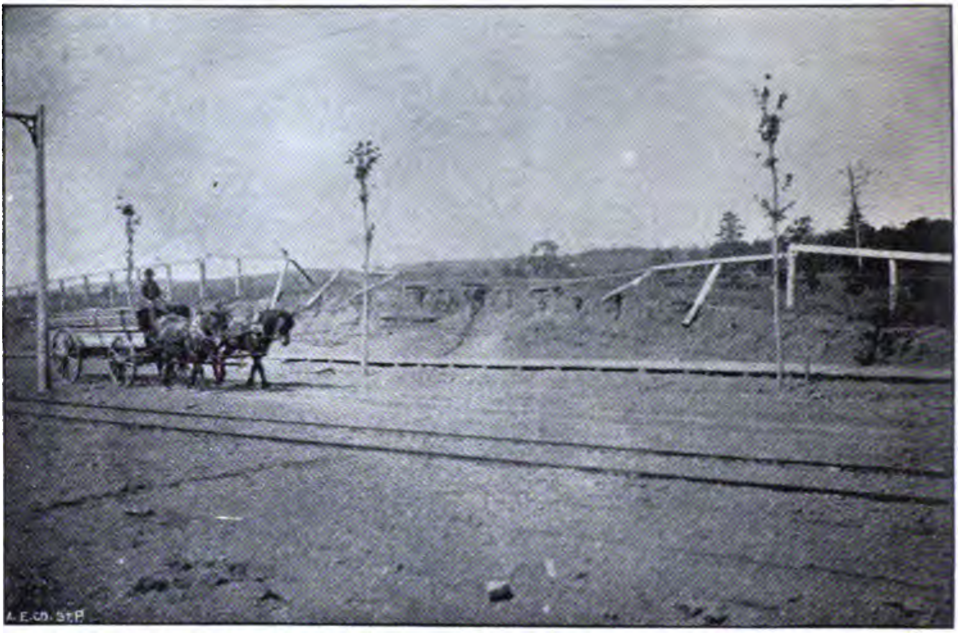

FIG. 1. GRAVEL CUT. SECTION ACROSS HARDY'S SCHOOL HOUSE BEACH, EAST DULUTH. (P. 237.)

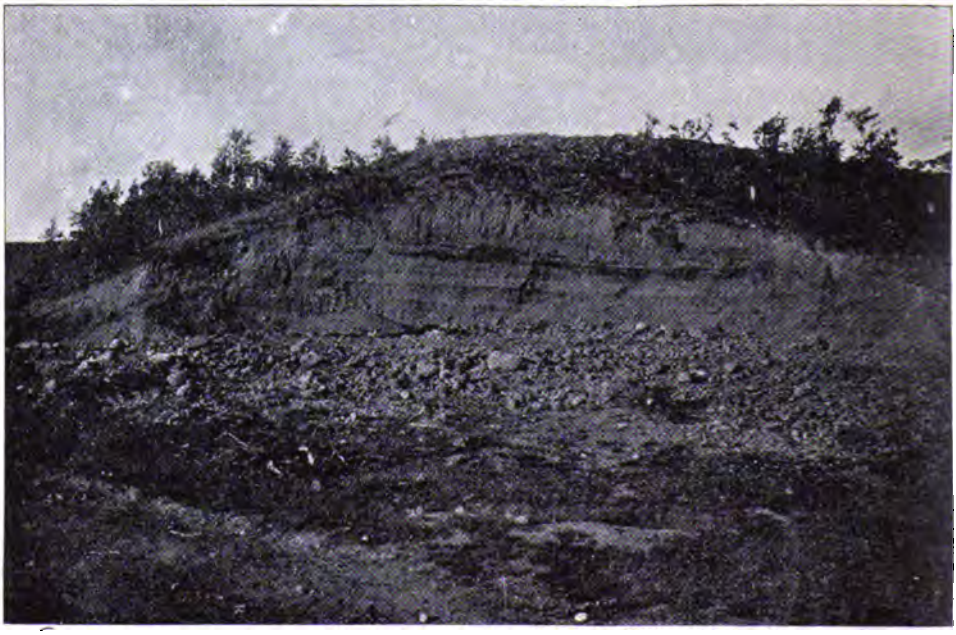

FIG. 2. CUT IN GRAVEL BANK, SHOWING STRATIFICATION OF OLD BEACH, DULUTH. (P. 233.)

of the valley it spreads out and grades into a broad delta. The crest of the beach is higher than the valley bottom to the north of it and also higher than the flat tract to the south. The section referred to on the line of the tramway near the schoolhouse is a cutting made in the construction of the road and displays a vertical section of about 6 feet of evenly bedded and obliquely bedded gravels with some sands. [See Pl. X, Fig. 1.]

On the lower slopes of the eastern part of the city of Duluth and for many miles northeastward along the coast, there are definite indications and suggestions of terraces when the land is viewed from a distance. There are two circumstances, however, which interfere with the recognition and location of these terraces at close quarters. The first of these is that the geological structure of this part of the coast is such that the strata dip lakeward at about the same angle as the slope of the terraces, so that the changes of inclination in the transverse profile are not sufficiently accentuated to permit of reliable determination of the line of the abutment of the terraces upon the hill-side. The second unfavorable circumstance is the prevalence of timber which obscures the surface but allows the general effect of a terrace to be sometimes dimly apparent at a distance. On account of these conditions, no time was spent in trying to locate shore lines between Duluth and Two Harbors.

*Series 4.—Two Harbors (D. & I. R. Ry.).*—On the line of the Duluth and Iron Range railway, northward from Two Harbors, one very strong suggestion of a strand line may be observed in the vicinity of mile post 32, in the abutment of a sloping plain against a series of morainic hills. This change of the character of the surface comes out most distinctly when viewed from a distance. From a hill top on the shore of the lake near Two Harbors, even although the country is wooded or only partially burnt, the effect of a plain abutting upon the hills is quite distinct. The corresponding change in the slope of the surface is recorded in the railway profile as published in Winchell's Iron Ores of Minnesota, plate No. XXXVII, where the rear of the terrace at the 32nd mile post is given at 475 feet (XXIX).

The railway yards and station, at the town of Two Harbors, are also on a terrace whose limitations to the northwestward could not be definitely recognized. The elevation of this plain at the railway junction is, according to the same authority, 35 feet above the lake.

*Series 5.—Beaver Bay.*—The mouth of Beaver river is well protected from south and southeast winds by a bold head, which, at its extremity, presents to the lake vertical cliffs over 100 feet high, but which is connected to the main land by a rocky ridge about 50 feet on an average above the lake. This ridge is partially mantled by old beach material and sand. The stream, after emerging from the gorge through which it discharges into the lake, hugs the northeast side of this protecting ridge for a couple of hundred yards, and on the other side of the stream there has been built up, by the joint action of the stream and easterly or northeasterly storms, a well defined spit. [See Pl. XII, Fig. 2.] This spit seems to be crowding the stream against the ridge, and in consequence it is cutting a terrace in the soft material which flanks it. This same condition of things seems to have obtained when the lake was 20 feet higher than at present; for, on the northeast side of the ridge, parallel to the present stream, and 20.1 feet (III) above it is a distinct terrace, which, while doubtless due to stream action, yet is in such a position that it must have, at the time of its formation, corresponded at its rear to the then level of the lake.

The next old strand line observed at Beaver bay is on the slopes above the base of the spit referred to, where a small but distinct terrace is found at an elevation of 79.9 feet (VII). The terrace looks out over the lake and lies to the northeast of the mouth of the gorge from which the stream emerges. The hill in which the terrace is cut is apparently moranic material resting in a rocky slope. There is doubtless also an admixture of stream detritus but the heavy sward prevents satisfactory determination of the structure of the hills.

Farther up on the slopes of this hill a broad terrace has been built up evidently in the form of an embankment of the stream detritus dumped into the lake at its higher stages. This terrace is best seen in the cultivated fields on the west side of the Beaver river. It abuts against the steeper hills as an old shore-line near the grave-yard at an elevation of 126 feet (XI). A few hundred feet down the slope of this broad and gently-sloping terrace is a low beach-like ridge of fine gravel which is probably of the character of barrier beach at 114.8 feet (X). On the east side of the river the hill rises somewhat uniformly in the form of a broad sloping well timbered terrace. A wagon road through the timber shows that while the slope is uniform in general it is uneven in detail, is strewn with boulders, and characterized by abundance of red mud. This broad terrace at about a mile back from Beaver bay encircles a rocky hill which rises from the rear of the gentle, nearly flat slope with steep sides which in places are absolutely vertical for over one hundred feet. The sides of the hill at these places present the character of a sea cliff and the abutment of the gentle boulder-strewn terrace against this rocky hill is taken to be the mark of an old strand line, at a time when the hill was an island of the lake. This abutment was found by our measurement to be at 313.9 feet above the lake (XXII). The hill thus encircled has a diameter of perhaps one-half mile and rises to about 700 feet above the lake. It was ascended to the summit, but no red mud and very few boulders were seen above the terrace plane. Nor were any indications of higher strand line observable either on this hill or on the surrounding hills as seen from its summit. The summit affords a good view of the surrounding country and the terrace in question appears to run in between the hills as a valley bottom which as far as could be judged in the timbered state of the country, rose on the flanks of the hills to a constant level. Between this hill and the lake on the general slope of the main terrace there is a subordinate terrace at an elevation of 173 feet (XV).

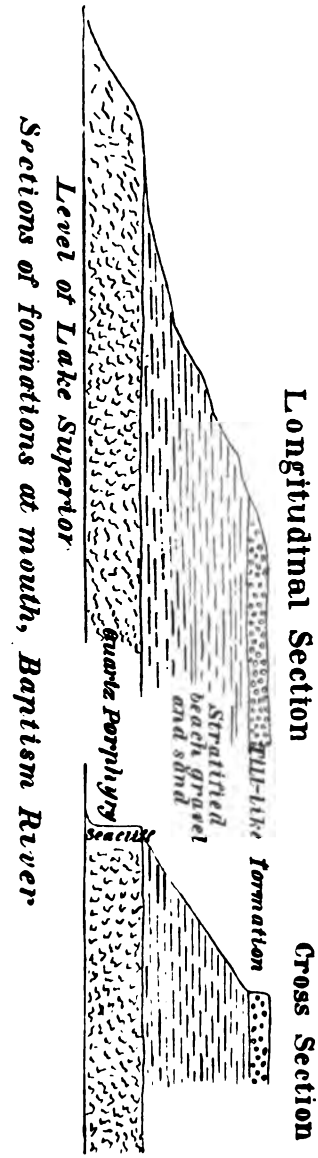

Fig. 9. Sections at mouth of Baptism river.

*Series 6.—Baptism River—* Just east of the mouth of the Baptism river below the Palisades, a clear-cut sea-cliff facing the open lake reveals a unique and interesting section. The cliff rises practically from the present level of the lake, but there is a low beach a few yards wide between its base and the edge of still water. The lower 30 feet of this sea-cliff is vertical and consists of one of the acid formations of the Keweenian volcanic series which are usually so intimately jointed and so susceptible of mechanical disintegration. Upon this rock rests a thickness of over 50 feet of stratified material which presents all the characters of a shore embankment.

It is made up chiefly of coarse sand, gravel and boulders entirely uncemented. Upon this stratified beach-like material rests about 11 feet of heterogeneous material which has all the characters of boulder till. The part of the sea-cliff above the lower vertical wall of rock, although made up of these incoherent materials, presents at numerous places a vertical escarpment in its upper part with a talus mantling its lower part down to the brink of the rocky cliff. The section parallel to the shore, as seen when approaching the shore from the lake, is shown in Fig. 9, as is also the cross section.

The upper incoherent portion of the sea-cliff although presenting a front which stands somewhat further back from shore than the lower rocky portion is not apparently receding at a faster rate, but is receding *pari passu* with the undermining of the rocky foundation on which it rests. The line of demarkation between the rocky lower portion of the sea-cliff and the stratified material which rests upon it is a roughly horizontal one and seems to be the trace of an old plain which is of the nature of a terrace. The dividing line between the stratified beach material and the third or till-like member of the section, is also a horizontal line and is sharply marked. There seems to be no good ground to doubt the beach character of the middle member of the section for the following reasons: (1). The character of the material is that which usually constitutes shore drift. (2). Its stratification is similar to that of embankments composed of material not too coarse. It is both horizontally and obliquely bedded, the planes of the false bedding being frequently discordant. (3). The apparent embankment extends out from the west side of a bold promontory which lies to the east of the Baptism river and the material is coarser near this rocky ridge than further from it. (4). It faces the open lake and extends across the front of a valley. In view of these facts the formation is interpreted to be an embankment of the character of a beach bar that once crossed or partially crossed the mouth of a bay into which the old river discharged. The material of which the embankment is built is partly foreign, doubtless brought by the stream from morainic accumulations inland, and partly local from the mechanical disintegration of the cliffs. The upper member of this section, as has been stated, presents the heterogeneous character of boulder till. In places it is a pure red plastic clay with only occasional pebbles in it, but quite devoid of structure; a few yards away this will merge into a clay mixed with sand and pebbles in the most irregular fashion, together with numerous boulders both rounded and angular up to two feet in diameter. Could the formation be shown to be boulder till of glacial origin, the section would be of great interest in connecting the old high leads of the lake with the presence of glacier ice at a time posterior to the primary glaciation of the region. The suggestion that this till-like formation is of glacial origin is sustained in a measure by the fact that it is found at the mouth of a short valley at the upper end of which are ranges of hills much higher than are usually seen on this coast, and which might have served as a gathering ground for local glaciers. In spite, however, of these suggestions of glacial causes, the origin of the formation must be for the present regarded as problematical, and the evidence inconclusive. In some of the western placer mining districts the heavy beds of stream detritus, consisting of boulders and pebbles of greatly varying sizes imbedded in clayey matrix, and devoid of definite arrangement within a given bed of great thickness, resemble closely much of the material which sometimes is called boulder till and referred to glacial origin.* In view of the insufficient examination of the surrounding conditions nothing beyond suggestion is offered as to the origin of the till-like stratum. It is assumed that the summit of the stratified gravel is the approximate crest of a barrier beach which by some means has been covered by the till. The summit is 83.8 feet above the level of the lake and it thus falls into place with strand line VII. On the upper or westerly side of the mouth of Baptism river, behind the club house, there is a distinct wave-cut terrace which has been carved out of a morainic accumulation, the rear of the terrace being 49.0 feet above the lake (V). The terrace has a very low angle of slope and is strewn with boulders which project above the surface, giving it the character of a boulder pavement, in the sense in which Prof. J. W. Spencer uses that term. The sea-cliff behind the terrace is low and has been rounded by atmospheric waste. The morainic material rests upon the same terrace-like platform rock as that observed on the east side of the river. The terrace and sea-cliff face the open lake.

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*Formations of the character commonly designated as boulder clay may, it seems to the writer, in some cases have an origin greatly different from that at present ascribed to them and proper criteria of a purely petrographical character, so to speak, for discriminating between the true glacial formations and those due to other agencies are not yet formulated. Other criteria are of course available, such as the form of the mass, its relation to adjacent formations and other conditions of occurrence. But there seems great room for error if we rely on the character of the formation petrographically considered as a means of recognizing its mode of development.

*Series 7.—Saw-teeth.*—About three miles east of the mouth of Baptism river in the vicinity of the Saw-teeth, a search was made for terraces at a place where the country had been burnt and the jungle appeared to be passable. None were seen from the shore, and the fact that the search proved successful warrants the belief that at many places along the Minnesota coast ancient terraces and beach lines will be revealed as the timber is cleared. At the locality in question, a great embankment of shore drift mantles the underlying rocks up to a level of 130 feet above the lake. The upper limit of this embankment forms a horizontal contour around the hill and marks the rear of the highest terrace. Above it the hill rises with an acclivity of about 25 degrees to a hight of about 300 feet above the lake. The terrace has a slope of perhaps 5 degrees and at the place examined is about 150 feet wide. There is no trace of water-worn material on the rocky slope above the rear of the embankment, only scattered angular blocks of local origin; and from the summit of the hill no suggestion of higher terraces was obtained from an inspection of the surrounding, thickly-wooded hills. The terrace (XXI) probably belongs to the "cut and built" type of Gilbert, but no well-defined cliff has been developed and the accumulation of shore drift has been proportionately more rapid than the cutting action, a fact due doubtless to the proximity of streams. About 150 feet from the rear of the embankment, the upper terrace is limited by the sea-cliff of the next lower terrace. The sea-cliff, having been cut in the incoherent material of the embankment, is well defined, although its slope is something less than the angle of repose. The terrace at the base of this sea-cliff is only 50 feet wide and has an altitude of 99.5 feet (IX). Below this is another low sea cliff, the base of which is 84.5 feet high (VII), at the rear of a broad, gently-sloping terrace which extends for nearly one-fourth of a mile to the brink of the cliffs above the present shore.

*Series 8.—Carlton Peak*—From the vicinity of the Saw-teeth to Carlton peak fairly definite suggestions of two, and in some cases more than two terraces are obtained by an inspection of the coast from the lake. The country is, however, heavily timbered, and experience proves it to be impracticable to locate them within a reasonable time by crawling through the jungle. On the slope from Carlton peak to the shore the timber has been burnt, and by hard scrambling through the windfall it was possible to reach the terraces and ascertain their elevations approximately by aneroid observations. The figures obtained by this means were 80 feet, (VII) and 125 feet (XI) respectively, above the lake for the rear parts of two very gently sloping terraces that have been cut in a broad embankment of soft material which must have accumulated at still higher stages of the lake. The precise registration of these higher stages was not observed, but the conditions of examination were unfavorable, and it is probable that higher terraces on the flanks of Carlton peak will be found.

*Series 9 and 10.—Poplar River*—The Poplar river cuts through a broad embankment of sand, gravel, etc., which mantles the rocky slope of this part of the coast for many miles. The front of the embankment overlooking the lake descends rapidly to the present shore by a succession of cliffs and cut-terraces which have been carved out of the main embankment at various successively lower stages of the water subsequent to that at which it was accumulated.

The brink of the main embankment is about 116 feet above the lake, and from this point its upper slope rises very gently landward for nearly two miles to an elevation of about 300 feet where it abuts sharply against a steep range of a gabbro. The general character of the topography and the underlying structure is analogous to that described at Beaver bay, where a broad gently-sloping terrace of incoherent material abuts on precipitous rocky hills at an elevation of about 314 feet. The rear of this broad terrace at Poplar river was only ascertained very approximately by an aneroid observation, so that the figures are not incorporated with the more precise data of the table. The wooded character of the country practically prevented precise observations at points distant from the shore without an expenditure of time, labor and money, which would have been inconsistent with the modest plan of our operations. Although the newer terraces carved in the front of this main embankment face the open lake, they are in the immediate vicinity of the mouth of the stream, and the stream currents have doubtless played an important part in the development of the terraces, supplying and removing detritus contemporaneously with the cutting action of the waves The terraces and cliffs are all remarkably sharp in cross profile. The terraces are narrow and vary but little from horizontal. The angle of slope of cliffs was carefully measured and three were found to have a declivity of 28°, two of 27°, and one (the lowest) of 32°.

The lowest terrace of the series is a wave-built terrace, and is only 6.9 feet (I) above the level of the lake at its rear, where the fishermen's boat-houses stand. Towards the lake it grades into the present shore. The higher terraces have none of the characters of wave-built structures so far as can be discerned. At the summit of this series of terraces and cliffs, just at the limit of the main embankment, is a beach-like ridge with somewhat lower ground behind it and a series of minor, succesively lower, parallel ridges on its gentle lakeward slope. This ridge is interpreted to be a barrier beach developed at a favorable stage of the emergence of the coast. The accompanying cross profile was plotted to scale in the field from precise measurements.

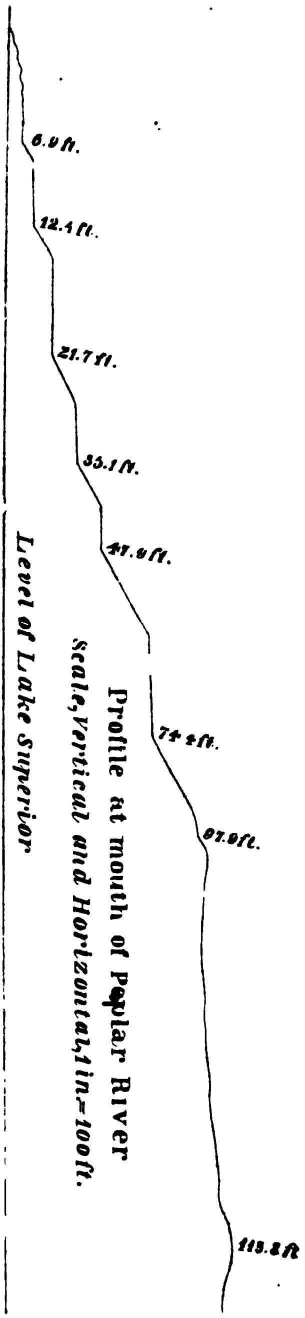

Fig. 10. Profile at mouth of Poplar river.

On the east side of the mouth of Poplar river only three distinct strand lines have been registered on the front of the main embankment. These are, a well-formed wave-cut terrace facing the lake at an elevation of 78.4 feet (VII); a less distinct terrace, which is seen in vertical section where the river gorge cuts it, to be composed of stratified gravels, the elevation of its summit being 99.6 feet; and again a beach-like ridge, the highest line on the front of the embankment, at 116 feet.

*Series 11.—Coast east of Poplar River.*—East of Poplar river two terraces are observed to follow the shore more or less continuously for some miles. Both are covered with timber, but as they are low and not usually distant from the shore, their topographic character is not obscured beyond recognition. Both are wave-cut terraces and have been carved out of a primary embankment which mantles the rocky slopes of the coast. These terraces were found to be susceptible of partial measurement at a fishermen's clearing about two miles from Poplar river. Here the brink of the lower terrace is 14.5 feet above the lake, the front limit being a steep sea-cliff rising from the present shore. The terrace is 150 feet wide and at its rear has an elevation of 17.8 feet (III), thus exhibiting a slope of about 2 in 100. From the rear of this terrace an other sea cliff rises with a slope of 37 degrees and the brink of the second terrace is 37.5 feet above the lake. The terrace runs back under the beach apparently nearly flat. The elevation of its rear portion was estimated to be 6 feet higher than its brink, thus making the shore line about 43.5 feet (V) above the lake. The low sea-cliff which rises above the present shore and limits the lower terrace lakeward is rather a striking feature of this part of the shore, being a vertical scarp of the old embankment material resting upon rock varied in places by shorter stretches in which the cliff is wholly rock or wholly embankment gravel.

*Series 12.—Good Harbor Bay.*—The next locality along the coast where the ancient strand lines are sufficiently recognizable to be measured is at Good Harbor bay. The bay is open to the east and northeast and presents on the maps but a small jog in the generally uniform trend of the shore. The west side of the bay is overhung by a sea-cliff of very slightly inclined beds of red and brown shales and shaly sandstone which rises vertically to a hight of 15 feet. Between the base of the cliff and the shore line there is a narrow and low beach of shingle derived chiefly from the cliff. Above this sea-cliff there is a terrace about 100 feet wide and 20 feet high at its rear (III), which is thickly strewn with shingle. Immediately above this, with a low cliff between, is another terrace 25 feet wide and 27.2 feet high at its rear (IV), and also cut out of shingle and gravel. A third sea-cliff cut out of irregularly stratified gravels and sands of a primary embankment rises above this for about 50 feet. Above the summit of the cliff the ground rises gently in a rolling succession of beach-like ridges for several hundred feet horizontally and then grades into a distinct terrace abutting against the higher slopes of the hill at an elevation of 115.3 feet, (X).

*Series 13.—Grand Marais.*—The pinkish acid volcanic rocks of the vicinity of Grand Marais have by their mechanical disintegration along the sea-cliffs afforded an abundance of shingle and gravel with which the waves have banked up a fine series of beaches. These have been arranged in parallel ridges in the form of a beautifully distinct and typical wave-built terrace. As this terrace encroached upon the area of the lake the space between the shore and the rocky island upon which the lighthouse stands was spanned by a spit, and the construction of the terrace was limited to the northeast side of the resulting bar, since the latter closed in a bay, the only entrance to which is by a deep channel between rocky points through which no shore drift could enter. [See Pl. XII, Fig. 1.] Within the bay at Grand Marais the wave action has been restricted, for lack of supply of new material, to working over the old material brought there before the bar was established; and its effect has been doubtless to extend the size of the bay and render it shallow. Within the bay the crest of the living beach has an altitude of 5.5 feet and is 23 feet distant from the water. Parallel to this and 65 feet farther inland across an intervening hollow is an old beach, the crest of which is 6.1 feet above the lake (I). Behind this is again a hollow and beyond the ground rises in two low steps to culminate in a third distinct and bare beach-crest at a distance 105 feet from the second. The altitude of this third beach is 12.1 feet (II). This is again followed landward by a parallel hollow, and again the ground rises (all bare shingle and gravel) in two low steps, each about 25 feet broad, the higher of which is 17 5 feet at its edge. Neither of these steps is taken to mark a definite stage of the water. The upper of these steps grades into a gently sloping wave-cut terrace 260 feet wide and 29.1 feet high at its rear. Thus from the back of this terrace (IV) to the present shore there appears to have been no sudden drop in the level of the lake but a gradual recession of the water. At stage IV the waves were cutting a terrace out of a pre-existent embankment of shingle and gravel. As the water sank the supply of drift from neighboring cliffs seems to have increased so that terrace-cutting gave way to terrace-building. The particular section selected for measurement shows the wave-built terrace at its narrowest part. Farther east it is many times broader.

Along the line of examintion the cutting action which produced the terrace of strand IV had eaten back into an embankment of shingle to the line of a beach of a former higher stage of the lake. For at the rear of the terrace a low sea-cliff of shingle rises with a slope of 28 degrees and this slope is nearly coincident with the front slope of a very distinct shingle beach with a hollow behind it, the crest of which is 43 6 feet above the lake (V). Above the level of this beach, the slope of the hill rises gently with an undulating profile, and presents a surface of gravel obscured by forest loam and shrubbery. In this vaguely undulating profile which was plotted to a large scale with great care, in the field, only two shore lines are distinctly registered, viz: one at an elevation of 55.9 feet (VI), in the form of a terrace 26 feet wide, and another at 113.5 feet (X), where the last of the gravel was observed.

Less than half a mile farther west, however, two still higher strand lines were observed and their altitudes measured. The lower of these is a terrace 127.3 feet high (XI) which is well seen from a distance towards evening, but which is less apparent at close quarters. The higher is a distinct but not an extensive gravel terrace encircling low glaciated domes of rock at an elevation of 162.6 feet (XV). This upper terrace is nearly on a level with the lower part of the bold bluff which overlooks Grand Marais on its southwest side. This bluff presents vertical walls from 20 to 50 feet high and was a sea-cliff when the water stood at the 162 6 foot level. On the east side of Grand Marais village a trail goes up over the hill. This was followed to the summit of the pass, about 750 feet above the lake, in search of higher strand lines. But although the trail passes almost continuously over morainic accumulations, no trace of a shore line was observed at levels higher than that last recorded.

*Series 14.—Kimball's Creek*—From Grand Marais eastward a low terrace, corresponding to strand line IV or the 29.1 feet terrac at Grand Marais, may be observed for several miles along the coast as far as Cow-tongue point. Higher traces of shore lines are doubtless present, but they are utterly obscured by the jungle. At the bottom of the bay below Cow-tongue point three terraces are observable from the lake, but only two of these could be located. The third eluded our search although it must have been covered by us in our excursion in quest of it near Kimball's creek; and the second was difficult to locate with precision on account of the lack of contrast between its slope and that of a pre-existent slope of rock in which no cliff had been carved. This terrace has a measured minimum elevation of 80.1 feet (VII), and its maximum is within two or three feet of this figure. It is evidently neither a wave-cut nor a wave-built terrace, but might be classed as a current-built terrace. Below this is a flat clearing on which stands a half-breed's house. The flat is the first of the three terraces referred to. At its rear it is 28.5 feet high (IV), and above it rises a steeply inclined sea-cliff carved out of the primary embankment, whose upper surface constitutes the second terrace. Farther along the shore this terrace is again seen about a mile below Fish-hook point, and again below the mouth of Brulé river, where it is being cut into by the wave-action so as to present the scarp of a sea-cliff rising above the existing shore.

*Series 15.—Horseshoe Bay.*—At the bottom of Horseshoe bay there is a very remarkable and striking series of three beautifully developed beaches. The bay, as its name implies, is not long proportionate to its width, but its shores converge towards the upper end and the wave action has been exceedingly energetic in consequence of this rapid convergence. Vertical cliffs of massive gabbro in the vicinity of the bay, particularly on its west side, where they rise to an elevation of 50 feet, have supplied the material of which the beaches are constructed. There is also a sparing admixture of glacial erratics. The remarkable feature about the beaches is that there is no shingle or gravel or any fine material whatever in their composition. They are strictly boulder beaches resembling ridges of cannon balls, although there are as many sub-angular boulders as rounded ones. [See Pl. VIII, Fig. 2.] The crest of the lowest of these beaches is only 20 feet horizontally distant from the present shore line and its crest is 11.9 feet (I) above the lake. The crest is strikingly horizontal and curves parallel to the contour of the shore. It may be the storm beach of the present stage of the water, but the size of the boulders which range on an average from 6 inches to 12 inches in diameter, suggest that the crest was built up when the water was somewhat higher than now. Behind this beach there is a slight depression and behind this the second boulder beach rises to an elevation along its crest of 17.6 feet (II). The distance between the two beaches from crest to crest is about 100 feet. The boulders of which this beach is composed do not on the average vary much from 12 inches in diameter. This second beach is again followed by the usual parallel hollow and behind this rises the third and most imposing beach of the three. The crest of the latter is 200 feet distant from that of the second beach and is 38.6 feet high (IV). The front of this beach is not a simple slope as is the case with the two lower beaches, but its profile shows a distinct step-like feature in its lower part such as may be some times seen in clear water on the subaqueous slope of some of the living beaches of the lake. The component boulders of this beach are perceptibly larger than those of the lower beaches, the average diameter being over 12 inches. Many were measured which greatly exceeded this dimension. This beach was clearly developed as a bar across the bay when the water was at stage IV, for behind the beach there is a broad expanse of marshy ground much lower than the beach, which represents the lagoon formed by the establishment of the beach bar. At higher elevations of the surface of the water, Horseshoe bay would have been merged with the common expanse of the lake and the shore carried further inland than the range of our observations.

*Series 16.—Double Bay*—A fine display of terrace topography, visible through the burnt and still standing timber, meets the view on entering Double bay. The present shore line is backed by a steep sea-cliff which is being carved out of an embankment which is probably fundamentally morainic, although modified in form by shore action of former high stages of the lake. Numerous boulders are worked out of the embankment and are strewn along the present shore, but it is largely also composed of clayey material. Stretching back from the brink of this sea-cliff is a nearly flat terrace, which is about a quarter of a mile broad, and which spans the entire breadth of the embayment. The rear of this terrace is about 32 feet above the lake (IV). Above it rises a second sea-cliff followed by another broad terrace similar to the first, having an altitude at its rear which measured 85.8 feet (VII). This second sea-cliff is not continuously distinct. Above it spreads out a broad sloping plain which varies in width, according to the topography of the rocky slope which here begins to emerge through the superincumbent embankment. Along the line of section measured, this terrace is about a half mile wide and abuts upon a rocky slope; the line of abutment is horizontal, and although no well-marked sea-cliff has been developed, owing to the resistant character of the rock, it may with great probability be taken to mark approximately a shore line. Its elevation, as measured is 160.5 feet (XIV). On top of this rocky ridge at an elevation of 278.9 feet, and at a distance inland of about a tenth of a mile from the rear of the last mentioned terrace was found a distinct gravel bar surrounding low rocky knolls and spanning the gaps between them. To the northeastward this beach appears to merge into a terrace which abuts upon the precipitous flanks of a spur of Farquhar's Knob. The rear of this terrace would be a few feet higher than the figures given for the elevation of the gravel bar, but its precise elevation was not determined. It doubtless corresponds to strand XXI.

*Series 17.—Grand Portage*—It was hoped from a distant inspection of the topography of the pass through the hills at Grand Portage, from its being fairly free from timber, and from its gentle grade, which renders the country accessible for some miles from shore within moderate limits of elevation, that the registration of the ancient strand lines of lake Superior would at this place be fuller than usual. This hope was, however, not fulfilled, and only a few of the strand lines were satisfactorily located by carrying a line of levels along the portage trail. From the nature of the embayment in the hills it is evident at a glance that at the higher stages of the water Grand Portage bay must have extended several miles inland and have had a somewhat irregular shore contour with sharp indentations, particularly on its west side. From the precipitous character of the bluffs or promontories which limit the embayment on either side it is presumed that very little of the general shore drift found a lodgment in the bay, and whatever embankments may have accumulated would be of local derivation. The fact that the general shore drift did not find its way into the bay at the higher stages of the lake, either around Mt. Josephine on the east or the bold precipices which rise on the west of the embayment, is evidenced by the absence of such drift on the wave-cut terraces which contour these precipitous slopes on either hand, as will be noted later. In spite of this exclusion of the general shore drift, there is evidence that at probably all recorded stages of the water, the water was in the middle parts of the bay as it is now, always shallow, and that waves, although very effective on the neighboring steep slopes where the water was deep, left comparatively feeble traces of their action on the successive shores at the head of the bay. The conditions which have favored an excessive accumulation of local detritus in the bay and rendered it shallow from the highest stages of the lake down to the present are, (1) the presence of a massive morainic ridge crossing the valley about four miles north of the village, and, (2) a small stream cutting through it which has built up a succession of sloping delta plains, each of which has been cut through in turn as the level of the lake dropped. The higher and older delta plains appear to be much more extensive than the later, and it is a possible case that at the time of their building the stream flowed from beneath ice still lingering behind the moraine in the upper part of the valley. The highest delta forms a very distinct broad plain which has been terraced by the stream, but which cannot be clearly separated at its rear from the present front slope of the moraine. Half a mile or more in front of the moraine there projects through the plain a rocky glaciated dome a few hundred feet in diameter. The abutment of the plain upon the steep slopes of this island-like mass of bare rock is very sharp. An inspection of the surface of the rock, which is uneven in detail on top, warrants the belief that it was not submerged at the time of the formation of the plain which encircles it, and that it was, therefore, but little above the level of the water which conditioned the slope of the plain. The elevation of the plain at this point was measured at 339.7 feet, which altitude is placed in the table as representing approximately strand line XXVII.

A higher terrace was also observed abutting on a rocky slope at an elevation of 458 feet, but the brushy character of country obscured its relation to that just mentioned and it could not be determined to be distinct from it.

Further down the valley on a lower delta slope are two low beach-like ridges, one at 254.7 feet (XX), and another at 231.8 feet (XVIII), which appear to have been barriers thrown up by the breakers in a shallow bay at some distance from the shore and similar to the barrier which is now forming in Grand Portage bay. On a still lower delta plain and much nearer the lake is still another low barrier ridge which has an elevation of 103.5 feet (IX). The church of the village stands on a terrace which, at its rear, at the foot of a low and worn-down cliff carved out of delta material, is 74.7 feet high (VII). Immediately to the lakeward side of the church the ground drops steeply to the level of the terrace on which the village is built. This drop represents a sea-cliff which is one of the most striking shore features of Grand Portage. The terrace which extends out from its base is 37.9 feet above the lake (IV). There is still a lower terrace the rear of which is about 8.6 feet above the lake (I). The present bay is shallow out as far as Grand Portage island so that the waves break before reaching shore; and one of the results of this is the development of a subaqueous ridge or barrier parallel with the shore line. Boats drawing over a foot of water may ground on this barrier, but between it and the shore the water is deeper. The barrier as yet appears nowhere above the surface of the lake and probably it will never so develop into a barrier beach, but always remain subaqueous since heavy storm waves necessary for the throwing up of the initial subaerial ridge can not reach this line on account of the lakeward shoal.

*Series 18.—Mount Josephine.* The south side of Mt. Josephine presents a succession of strand lines most of which are exceptionally well defined. The mountain is a ridge about 800 feet high and consists of a great dyke of gabbro or diabase, to both of the steep flanks of which a selvage of southerly dipping slates and quartzite of the Animikie is still adhering up to varying elevations. The extremity of the ridge juts out into the lake as a sharp point which forms the eastern limit of Grand Portage bay and is known as Hat point. The most striking and most heavily scored of the strand lines is a wave cut terrace (XXX) which contours the side of the ridge at an elevation of 509.5 feet and sweeps around in a beautifully shaped curve where the ridge abuts upon the main mass of rock from which it is a spur. The timber has been burnt over a portion of the hillside so that the character of the terrace, as a heavily cut shelf, perfectly horizontal, projected against the side of the hill, attracts the eye from a long way off, and excites the curiosity of even the casual observer as a peculiar feature of the landscape. At close quarters the terrace was found to be about 100 feet wide, to have a gentle lakeward slope for this distance, and then to drop away into a steep declivity of the hillside. At its rear rises a steep cliff which is partly the side of the great dyke, partly the indurated slates adhering to the dyke, and partly a wall of the dyke rock, farther in than its original side wall, which has been established by the cutting action at the level of the terrace. The terrace is strewn with great blocks which have fallen from the vertical cliff, and at one place a considerable talus has accumulated in great part since the wave-action ceased. There is a considerable proportion of glacial drift over the lower flanks of the ridge and this seems to have extended up to the summit of the ridge since there are some northern erratics strewn over the surface of the terrace. It is possible that the terrace may in part, particularly at its northern end, be cut out of a morainic dump. The summit of Mt. Josephine is heavily glaciated. A small portion of beach shingle and gravel is strewn over the surface of the terrace. The possibility of the terrace being a feature of differential degradation was critically considered on the ground but all the evidence observed made clearly for its wave wrought origin. The facts that the strata dip southerly while the rear of the terrace is horizontal, that the slope of the terrace is outward and independent of the dip, and that the terrace character is maintained where it swings in the curve of the ——— away from the line of the dyke, indicate at once that its form and situation are not conditioned by the structure of the rocks. The terrace is further interesting as yielding to accurate measurement figures for its altitude which are identical with those obtained for the equally well-defined strand line (series 3) at Hardy's schoolhouse in East Duluth.

This terrace, although the most pronounced of the dents in the west side of Mt. Josephine, is not the highest. There are two higher and presumably older terraces, neither of which is so extensive along the hillside nor so wide. Both of these are much alike in their general character, and in the measure of their extent and they rise one above the other. They are continuous for only a few hundred yards and both vary from about 30 to 50 feet in width. Both are backed by a sea-cliff and both are strewn with blocks of rocks derived from it and from drift accumulations.

These terraces are respectively 587.2 feet (XXXII) and 607.3 feet (XXXIII) above the lake. One of them is a prominent feature of the hillside as a distinct horizontal shelf visible at long distance; the other is not so apparent, owing, doubtless, to the thickened shrubbery. It is suggested in explanation of their short extent, that they lie in a slight embayment on the side of this ridge and so somewhat protected; while their continuation on the more salient portions of the ridge has been undermined and cut away by the same wave action which resulted in the devlopment of the broader terrace at 509 feet. These two terraces at 587 feet and 607 feet are remarkable for being the highest strand lines which have thus far been observed on the coast of lake Superior.

Lower on the same slope of Mt. Josephine are two other sharply scored but narrow terraces which lie well within the unburnt timber and which are therefore not apparent at a distance. The first of them in descending order is at an elevation of 313.5 feet (XXII) and the second at 226.1 feet (XVIII). Both are readily observable on the trail which crosses Mt. Josephine from Grand Portage to Wauswaugoning bay, and both appear to be cut out of the accumulation of drift which here mantles the rocky base of the ridge. Still further down at the base of the hill is a boulder beach (V) the crest of which is 43 feet above the lake; and between this and the shore there is again a drop in the general slope to an even terrace which is 19.9 feet (III) high at its rear, and which extends for less than 100 yards to the brink of the sea-cliff of the present shore. This last sea-cliff has a hight of 13 feet.

*Series 19.—Wauswaugoning Bay.*—Wauswaugoning bay is limited on the southwest side by Hat point and on the northeast by the base of Pigeon point. The shore along the side of Hat point is a precipitous cliff without a beach or visible shelf at its base, and the water is deep. This line of high cliff, rising in places to a hight of 800 feet, is continuous around the embayment, but leaves the shore line about half way from the extremity of the point and sweeps round to the vicinity of Pigeon falls roughly parallel to the shore, but usually several hundred yards distant from it. At the base of Pigeon point the ground is low, and at higher stages of the water Pigeon point was either an island or was completely submerged so that portion of the sediment of Pigeon river then found its way into Wauswaugoning bay. But as Pigeon river is a new stream, being a succession of cataracts and stretches of still water, the sediment is small in quantity and very fine so that it supplied practically no material which would remain in the zone of shore drift on a wave-beaten shore. Its sediments have taken the form of a delta at the head of Pigeon bay where protected from wave action. The Pigeon river is clearly a very recent drainage and it seems probable that the ancient outlet was into Grand Portage bay. This dearth of stream detritus has characterized the shores of Wauswaugoning bay at all stages of lake Superior, there being no other stream cutting through or tumbling over the cliffs which rise around it. In this respect the bay presents a marked contrast to the neighboring bay at Grand Portage with its heavy deltas. The contrast between the two bays is perhaps best seen in the character of the strand line registrations. The higher stages of the lake were not strongly registered at the head of Grand Portage bay because of the lack of contrast between the subaerial and subaqueous slopes of the delta. At the head of Wauswaugoning bay the water line of the higher stage was not registered at all, because the shore was along the face of vertical cliffs of pre-lacustrine origin. As the lake subsided the water surface reached the talus of the cliffs and terrace lines were doubtless carved. But in the vicinity of the cliffs the growth of the talus since the water subsided has rendered them unrecognizable; and it is only when we come to comparitively low stages of the lake, where on the gentler slopes of the talus, conditions have been favorable for the carrying of a bar across the head of the bay, that permanent strand lines have been established. These bars form two magnificent beach embankments with lagoon hollow behind and undulatory slope in front. They are composed entirely of coarse shingle of quartzyte and hard siliceous slate which mostly weather red. The vegetation has been burnt off and the crests are remarkably sharp and continuously horizontal lines, which by their color and distinctness give a striking character to the landscape. The upper of these two beaches is 76.5 feet (VII) above the lake and the lower 43.7 feet (V).

*Series 20.—Near Birch Island.*—Outside of Wauswaugoning bay on the south side of Pigeon point and about half a mile east of Birch island there is a fine display of storm beaches. The material of which they are built is the detritus of the reddish Animikie quartzyte which is the prevalent rock on this part of the coast. The shore is well exposed to southerly winds. The beaches although well developed are here only found at comparatively low altitudes, there being no high slopes upon which embankments of higher stages of the lake could be lodged. Three distinct beach crests rise one above the other all having the same general character. The first of these is within reach of the waves of the present stage of the lake and is possibly the living storm beach in process of growth or having attained its maximum growth. Its crest is sharp and uniformily level at 13.6 feet above still water (I). About 150 feet from this crest rises the second beach equally sharp and distinct, with an elevation of 17.4 (II). On the front slope of this beach is a subordinate shelf-like feature. There is no perceptible depression in the 150 feet of space between the two beach lines. The third beach crest is about 100 feet behind the second and there is a slight depression between the two. There is a depression behind the third beach, *i.e.*, between it and the rocky slope upon which it has been banked up. The third beach has an elevation of 21 feet (III). All three beaches are, like those of series 19, absolutely devoid of soil or fine material of any kind. There is no blown sand to obscure their characters as perfect wave-built embankments of shingle and gravel spanning the bay between two rocky ridges.

*Series 21.—Pigeon Point.*—From the abandoned ranch at the mouth of Pigeon river a trail crosses Pigeon point to the shore on the south side. This trail is transverse to the trend of the rocks and between the two main ridges is an embayment which opens to the south-east on the south side of the point. The trail in crossing this embayment follows the crest of a shingle beach which spans it. The total length of the beach is something less than one-eighth of a mile, there is no breach in it and behind it is a well defined lagoon hollow. The crest of the beach was found to have an elevation of 75.6 feet (VII). On the front of the embankment which culminates in this beach a second beach has been developed at an altitude of 56.6 feet (VI). It is probable that several other beaches lie between this and the shore, but the interval is heavily timbered and definite results are scarcely obtainable.

*Series 22.—Pigeon River.*—At the mouth of Pigeon river, on the Canadian side, there are three fairly distinct traces of shore action. They are found on the south side of the point of land which separates the canon of the Pigeon from Pigeon bay. The highest is of the nature of a short gravel bar, connecting two projecting masses of rock. It is about one foot lower in its middle than at the sides where it abuts upon the rock. Its elevation at the latter place was found to be 134.3 feet (XII). The fine character of the gravel (mostly of slate), and the low curvature of the bar indicates development under sheltered conditions, such as the local topography would suggest. On the lower flanks of the hillside are two distinct terraces, one at 60.8 feet (VI) and another at 18.2 feet (III), both of which are probably rather to be strictly interpreted as stream terraces of the Pigeon, but being at its mouth and below rapid water, they represent very closely the stages of the lake at which they were developed.

*Series 23—McKellar's Point.*—The south side of McKellar's point near its extremity, has afforded conditions eminently favorable for the accumulation of a series of shingle beaches, viz: A cove between rocky bluffs, high sea-cliffs on either side shedding fragments of quartzyte, hard slate and trap through various successive stages of the lake, and exposure to the full sweep of the lake from the south. The fact that the beaches have accumulated on one side of a narrow ridge-like promontory has insured them from intersection by drainage lines and thus they are remarkably perfect in form. They have been protected also by forest growths but these have recently been removed by fire up to about 100 feet above the lake, leaving the bare red banks of shingle and boulders. It is quite noticeable in comparing the different beaches of the series that the material composing the higher ones is coarser than that of the lower. In the higher beaches, the embankment is made up essentially of boulders in which the flattened shingle character is comparatively rare. They are mostly subangular and have an average diameter of over six inches according to deliberate estimate made on the ground. There is in these higher beaches nothing which might be termed gravel. In the lower beaches the shingle-like character of the drift is pronounced. Some of the higher beach accumulations have been cut into by the wave action at lower stages, so that a part of the old material of the higher beaches has been worked over in successive zones of shore attrition. It is possible that the lower accumulations may be mostly composed of material derived from the older and higher accumulations, and if so, the contrast in form and size of the pebbles would be accounted for. The same contrast in the character of the beach material was observed on Wauswaugoning bay though to a less marked degree.

The series of strand lines on McKellar's point is divisible into three parts. The highest is a boulder beach that spans the embayment at an elevation of 137.6 feet (XII). Between this and the next beach there is an interval of perhaps two hundred yards in which no distinct shore lines were observed. This beach constitutes the first of the three divisons of the series and seems to be distinct from those which follow. At about 100 feet altitude we come well within the burnt timber and at the same time upon the second division of our series. This division consists of a continuous succession of beaches extending over a horizontal distance of about 300 feet. The actual figures obtained by levelling were for the highest of the succession 101.4 feet (IX) and for the lowest 82.2 feet (VII). Between the two beaches at these respective elevations, there are three distinct intermediate ridges, of which the middle one is perhaps the most pronounced and has an elevation of 89.7 feet (VIII). The succession seems to indicate, without question, a gradual recession of the lake between stages IX and VII. Whether this gradual recession continued below VII or not cannot be inferred from the record of this series. For, at a lower level the lake, whether arrived at by a gradual subsidence or by a sudden drop, conditions of shore action were so changed that instead of wave-building wave-cutting set in. This resulted in the development of a distinct wave-cut terrace and corresponding sea-cliff, both carved out of the pebble embankment. The terrace is about 100 feet wide and the sea-cliff is 25 feet high, and rises with as steep a slope as it is possible for the loose material of the embankment to lie. The rear of the terrace was found to be 48.4 feet above the lake and seems to represent stage V. This sea-cliff and the shore features below it constitute the third division of our series of strand lines. On the front part of this terrace there has been built up a distinct but low beach or barrier ridge which has an elevation of 36.3 feet (IV). The front limit of the terrace is again a cliff, almost vertical in places and carved out of shingle. At the base of the cliff is a beach accumulation which seems to be the beginning of a wave-built terrace. The terrace effect is somewhat marked, although the embankment is narrow. The maximum elevation of the embankment at the foot of the shingle cliff is 8.4 feet (I) and it is within easy range of storm waves of the present lake.

*Series 24.—Thompson Island.*—On Thompson island there are three strand lines recognizable. Two of them are shingle beaches and the third is a line of wave wrought caves on the south side of the island. The island is a long narrow ridge composed of a great trap dyke with some subordinate dykes running parallel to it and blocks of horizontal strata lying between the dykes or adhering to their sides. The upper of the two beaches lies on the summit of the main dyke at about the highest point of the east end of the island. The altitude of its crest is 97 feet (IX). The lower beach is at the extreme east end of the island. Its crest was found to be 28.7 feet above the lake (IV). Both beaches are composed of clean shingle and pebbles free of all fine material and unobscured by soil. The development of caves on the face of the nearly vertical side of the main dyke seems to have been primarily conditioned by weak spots in the rock due to the inclusion of masses of slate in the trap. The occurrence of a series of them at the same level and having the same general character as some smaller caves developed on the present shore can only be referred to shore action. The caves are widest at the mouth and at the bottom; and the sides converge rapidly inward and upward. Those examined were about 20 to 25 feet in length, and were about 12 to 15 feet high, at their entrance. The floors sloped outward. After comparing them with similiar cavities on the present shore line a point was selected in the floor of one of these caves as representing most probably the water level, and it was found by measurement to be 45.6 feet above the lake (V).

*Series 25.—Shore opposite Flat Island.*—The trap capped cliffs of hard slaty sandstones which are so characteristic of the topography of Thunder bay have at all stages of the lake afforded an abundant supply of durable shingle, and the fact that only a small number of beach accumulations have been observed on the talus slopes of these cliffs is due to the presence of the timber which obscures them from view. Wherever conditions are favorable on this part of the coast for observation, by reason of fire having removed the timber, or by reason of such talus slopes being within a short distance of the present shore, the beaches are observable. On the shore opposite Flat island there is a set of three beaches which are entirely analagous to those described on McKellar's point. They have been built up on the talus which encircles a sharp projecting angle in a line of vertical escarpment. At the summit of the series is a great beach ridge whose normal hight was found to be about 105 feet (IX), but which at one place is somewhat higher and is irregular in its form, as if the effect of the storms at this projecting point had been exceptionally great. This higher part has a maximum hight of 109.2 feet. From this great beach ridge a continuous succession of later beaches extends down to a beach crest which has an elevation of 86.4 feet (VII). The intervening beaches are sometimes distinct and sometimes run into one another. They seem clearly to indicate, just as the beaches at McKellar's point do, a gradual recession of the waters of the lake through this distance. Below this lower beach there is again as at McKellar's point, a precipitous, here nearly vertical, sea-cliff carved out of the shingle. At the base of the cliff a broad sloping terrace extends out to the present shore. The rear of this terrace at the base of the cliff is found to have an elevation of 45.3 feet (V). On the front part of this terrace at a distance of 150 feet from the present shore is a low barrier beach, the crest of which is 8.8 feet above the lake (I). The entire series is well bared and the beaches above the sea-cliff are destitute of all vegetation and soil. The sea-cliff is remarkable for its precipitous, wall-like character, while composed of loose shingle. There is no cementing material whatever and the broad flat character of the shingle alone enables the cliff to maintain its form.

*Series 26.—Shore above Carp river.*—In the embayment of the coast next above that into which Carp river flows, the country has been burnt over partially, revealing some fine shingle beaches at the head of the embayment. These cannot be seen from the shore but may be viewed to advantage from a boat some distance out on the lake. They are about half a mile inland from the present shore. The embayment within which they lie is bounded by vertical walls of columnar trap resting on flat Animikie slate, the two walls converging and meeting at the head of the embayment. On the sides of this embayment, at the immediate base of the cliffs, is the remnant of a terrace which appears to be nearly flat and which was found to have an elevation of 164.1 feet (XIV). The terrace is composed of shingle and gravel with cliff debris much less water worn. Below this and spanning the embayment from cliff to cliff is a great embankment of shingle the summit of which is a perfect beach. The distance between the canon walls along the line of the embankment is not more than a quarter of a mile. There is no breach whatever in the embankment. Behind the beach, *i. e.*, between it and the talus of the cliffs which encircle the head of the embayment is a very pronounced lagoon hollow, the bottom of which is about ten feet lower than the crest line of the beach. The crest of the beach is 138.2 feet above the lake (XII). Against the front slope of this great embankment another beach also of large dimensions has been built at a lower stage of the lake. Its crest has an elevation of 122.5 feet (XI). A little below this at an elevation of 116.8 feet is another, but feebly developed beach which probably also indicates a distinct though short-lived stage of the water. The conditions of the embayment are, it is perhaps needless, to say, peculiarly favorable for the development of such embankments. The continuous line of cliffs, of which the embayment is but an indentation, would, below the base of the trap cap, shed a large amount of fairly hard but slaty Animikie sandstone for the formation of the shingle, which, traveling along the shore, from either quarter, would be entrapped in the embayment. The latter is in ground-plan, funnel-shaped, opening upon the lake and exposed to northeasterly storms.

*Series 27.—Carp river.*—The sides of the canon through which the overflow of Loch Lomond finds way to lake Superior by the short succession of rapids known as Carp river, contains numerous registrations of old strands, which are for the most part clearly defined. The canon is funnel-shaped, and has been an embayment at all the known stages of the lake. A wagon road ascends the canon to the level of Loch Lomond, a distance of about two miles, which renders the inspection of the topography of the canon an easy matter. Rising immediately from the present shore line there is a rolling succession of small, ill-defined gravel beaches at low levels which were not regarded as altogether simple in their development, but probably as having been modified by the stream which emerges at this point. They seem, however, to indicate a gradual recession of the water without leaving an emphasis at any one stage to suggest its longer continuance than its associate stages. The first well-defined beach has an elevation along its crest of 33.8 feet. (IV). This is followed by another great beach of perfect form at an elevation of 52.1 feet. (V). Above this are two terraces flanking the south side of the canon, one at 82.1 feet (VII) above the lake, and the other at 106.3 feet. (IX). Both are evidently current-built terraces and may owe their origin to stream action: but as their situation is near the mouth of the canon, their level corresponds very closely to that of the lake at the stages when they were built, unless the stream had a delta extending far out into the lake, a feature of which there is no evidence and which is highly improbable at the mouth of so short a stream arising from the overflow of a clear water lake. Further up the road is another great gravel beach which has been built up on the gently sloping surface of a great accumulation of stratified gravel which has once filled the canon, but is now cut through by the stream to bedrock again. The crest of the beach at the point leveled was 139.8 feet (XII) above the lake. The section afforded by the sides of the stream trench shows gravels to a thickness of nearly one hundred feet and proves that the canon as a feature of stream erosion antedates the high levels of the lake. Above this, on the north side of the canon, there are three small terraces, doubtless again essentially stream built, but also as argued above, representing closely levels of lake Superior. They were found to have the following elevations by our measurements, viz.: 221.8 feet (XVIII), 256.4 feet (XX), 288.1 feet XXI.

*Series 28—Pie Island*—The "Pie" of Pie island is a magnificent example of the *mesa* topography which is so characteristic of Thunder bay scenery. A roughly circular area of columnar trap, the remnant of a once extensive sheet, lies horizontally upon the flat Animikie slates. The edge of the trap, together with that portion of the slate which intervenes between it and the summit of the talus, presents vertical walls several hundred feet high. The top of the "Pie" is about 850 feet above the lake. This mesa was surrounded by waters of the lake at its higher stages beyond the general upper limit of the talus, and it is doubtless encircled by corresponding beaches and terraces on the slopes beneath the timber. There are strong suggestions of such features which even the timber cannot obscure. On the west side of the island the ground has been cleared and cultivated, and here on Mr. Keefer's ranch some of the strand lines stand out clearly and attract the eye at a distance of many miles. There are three of them which were sufficiently distinct at close quarters to permit of precise location. The highest of these is a broad terrace abutting upon the talus of the "Pie." It has the form of a great spit, the rear of which is 221.5 feet (XVIII) above the lake. It seems to be essentially a current-built structure, and there is no wave-built beach at its highest part, the material of the terrace being mostly fine gravel and broken shale. The crest or axial line of the spit, however, slopes downward or lakeward and seems to have been a salient of the shore line at various lower stages, at which its construction was continued, and upon the sides of which true beaches were thrown up. The profile, both along the axial line and transverse to it, is undulatory while regularly descending. Among several somewhat vaguely defined beaches which contour this complexly built spit, there is one very fine shingle beach which leaves nothing to be desired in the perfection of its form, its linear continuity, and its state of preservation. The crest of this beach was found to be 136.5 feet (XII) above the lake by our levels.

The third strand line is a broad terrace which along the line of our measurement abuts against a talus of great angular blocks of trap. Here it has an elevation of 43.5 feet (V) and slopes away from this altitude, without any marked break, to the low cliff above the present shore, in the vicinity of Mr. Keefer's house. More patient examination of the talus slopes of Pie island where the timber is thin, would doubtless reveal many other strands.

*Series 29.—Brulé Point.**—There is but one strand in this series, the coast being comparatively low. It consists of a well defined shingle and pebble beach in a small bay on the west side of the point. The crest of the beach was found to be 34.7 feet (IV) above the lake. This beach seems to be correlative with a broad terrace which extends far inland and which could not in the time given to the inquiry be discriminated from the plain of Kaministiquia delta. This delta has been developed at various successively lower stages of the lake and would require careful and very critical examination in order to win from it any record of definite and prolonged stages of its base level.

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*By an error printed Brulé *River* in the table.

*Series 30.–Kaministiquia.*—At the higher stages of lake Superior a large stream swept down the valley of the present Kaministiquia. At Kaministiquia station on the Canadian Pacific, this valley is constricted by the approximation of rocky hills which rise nearly 500 feet above the level of the railway at this point. Immediately below the station the valley begins to open out and continues wide and open to lake Superior. This narrow place in the valley seems to have been the head of the delta plain of the ancient stream. There is a gravel pit close to the railway station which reveals gravel and sand in false bedded attitudes. The pit presents a section of a very extensive terrace which appears to be the remnant of the old delta plain. This terrace adheres to the east side of the valley, the river in cutting its way down through it in pursuit of its steadily lowering base level having clung to the west side of the valley. But with such an open valley it seems probable that the waters of the lake which conditioned the apex of the delta were not far distant and that the level of the terrace at its abutment against the rocky slopes of the cañon indicate approximately the maximum figures for an altitude of one stage of the lake. The level of the terrace was found to be 455.1 feet above lake Superior. It is placed in the table as indicating a distinct stage of the lake (XXVIII) with considerable hesitation. It is not improbable that it should more properly be correlated with strand line XXVII.

*Series 31.—Port Arthur.*—In this series are some of the most beautiful terraces which have been noted among the strand lines of the north side of lake Superior. The series is also unique in comprising a well developed "*hooked spit.*" The effect of the terraces is strongly accentuated by the culture which has been imposed upon them. They are seen to best advantage, perhaps, within the town limits of Port Arthur, which is not yet so thickly built up as to obscure their character. [See Pl. IX. Fig. 1.] The lowest terrace is that upon which the business portion of the town is built. Its rear ends sharply at the base of a sea-cliff and was found to have an elevation of 61.4 feet (VI). From this altitude it slopes gently though not quite uniformily to the present shore through a distance in the heart of the town of about a quarter of a mile or less.

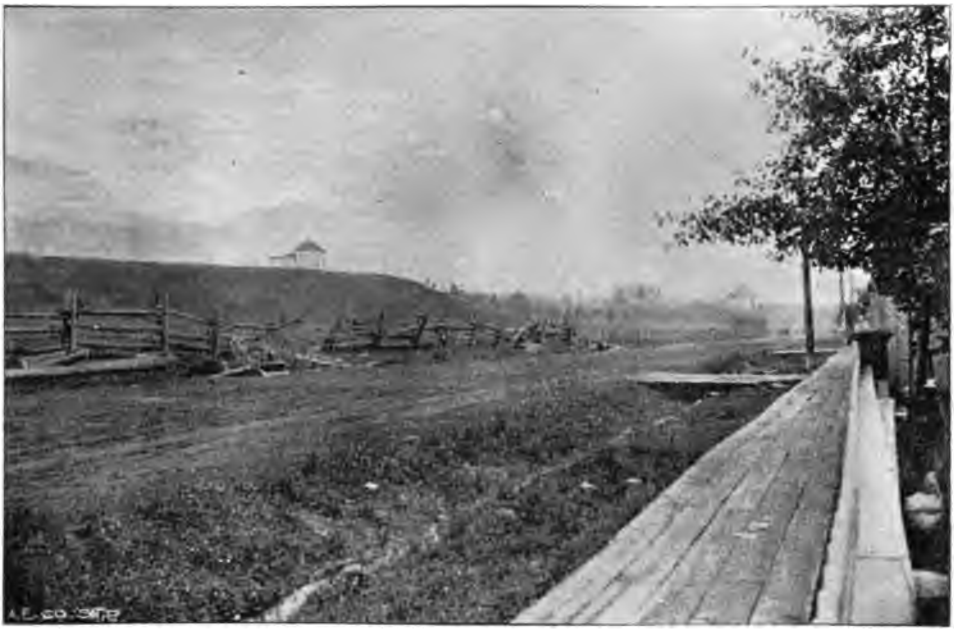

FIG. 1. TERRACE IN TOWN OF PORT ARTHUR. STREET ABOUT SIXTY FEET ABOVE THE LAKE. (P. 262.)

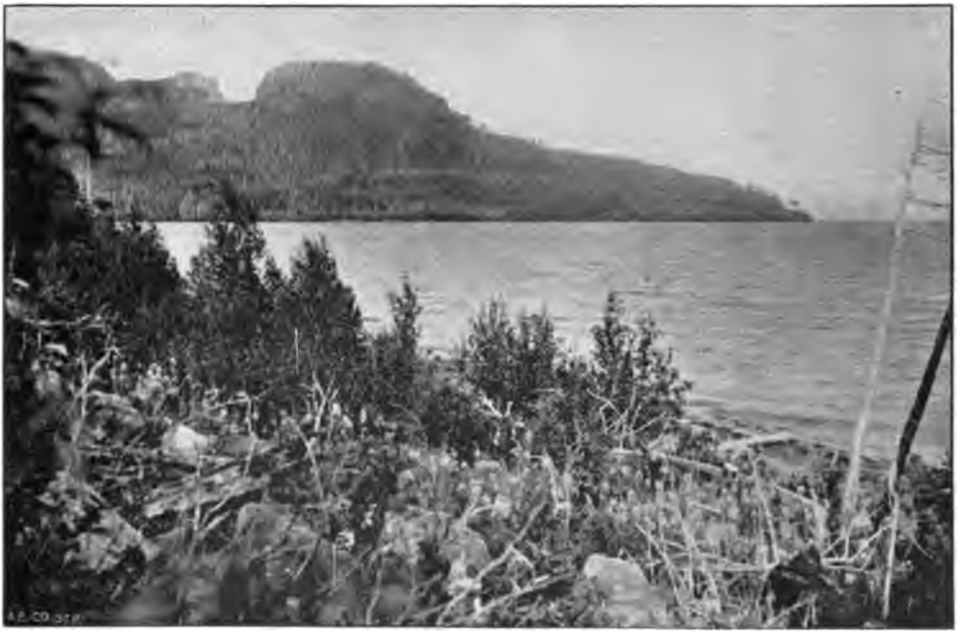

FIG. 2. PROFILE OF TERRACES AT BACK OF THUNDER CAPE. FROM SAWYER'S BAY. (P. 199.)

The next terrace is that upon which stands several of the churches of the town, the court house, and many of the more prominent residences. It has a very sharp brink at the upper limit of the sea cliff above referred to and is on an average less than half as wide as the terrace below it. Its rear is also remarkably sharp in its abutment upon its limiting sea-cliff. This sea-cliff is for the most part composed of the loose material of an earlier embankment, but in one place it is a precipitous wall of rock. The rear of this terrace was found by our levels to have an altitude of 89.8 feet (VIII). Above this are two remnants of higher terraces, one at 95.7 feet (IX) and the other at 118.4 feet (X), which, though narrow and not so sharply defined as the lower ones, appear as quite sharp and distinct lines when viewed from a distance. There is still another narrow terrace at 148.8 feet (XIII) which is rather illy defined and is not noticeable at a distance.

At the brink of the hill behind the town a little to the south of the Dawson road is a gravel pit which affords an admirable section of a beach. The beach crest runs out from a shoulder of the hill at the entrance to the valley of the Kaministiquia. The beach has been a spit which tended to continue its growth in the direction of the shore line from whence it received its material and so attempted to span the valley. Its extremity was, however, soon swung around so as to point up the valley, or bay as it was at the stage of the lake. In this way the characteristic form of a "hook" was developed and the form is perfectly preserved. The spit beach is somewhat remarkable for the number of large boulders which are strewn over its surface, while its section in the gravel pit shows it to be chiefly made up of comparatively fine gravel. The crest of the beach, at a point close to the base of the spit is 170.1 feet above the lake (XV). Its extent indicates a long continued stage of the lake.

*Series 32—McKenzie*—From McKenzie station, about 14 miles east of Port Arthur on the Canadian Pacific railway, a series of terraces can be seen scoring the hills to the north at a distance of probably a little more than a mile and a half to the farthest. An effort was made to locate these terraces by running a line of levels from the railway, but this only met with partial success. The terraces which appeared so sharp and unequivocal from the railway station lost their character when approached closely, and could only be recognized as terraces with considerable doubt. Some of these terraces, also, were of so remarkable a character that although figures for their elevations were obtained, they could not without more critical study be identified as strand lines of lake

Superior. Indeed only the broad sandy terraces immediately to the north of the railway, the lowest of the series, was found to possess sufficient of the character and definition of shore topography to warrant its being regarded as a strand. And even here the question had to be carefully considered whether it was not a flood-plain of the stream which traverses it, and the cliff at its rear a stream cliff. The material of which the terrace is composed, a stratified sand, seemed to indicate that it was not a flood-plain, but the bottom of a shallow bay of the lake, which the configuration of the hills suggests. Sections of the plain are well revealed in the cuttings and sand pits at McKenzie. This plain was found to be susceptible of very precise measurement. At McKenzie station it is 320.4 feet above the lake, and at its rear along the base of the cliff nearly a half a mile distant, it has an elevation of 326.8 feet (XXIII.) Above this are two shelf-like portions of the profile which suggest terraces, but the smallness of the one and the irregular surface of the other, render them doubtful as features due to shore action. The elevations of these are respectively 347 feet and 379 feet above the lake. Still higher is a much more distinct terrace at 420 feet above the lake, which would be interpreted as a wave-cut terrace were it not that, at its rear part, immediately in front of the cliff which rises above it, there are several very remarkable pits or kettle holes without apparent drainage outlet. The kettle holes have clearly originated after the development of the plain of the terrace. The pits were 15 feet to 20 feet deep, and irregularly funnel-shaped, and could apparently have been formed only by local subsidence of the ground. About 40 feet above this terrace, ascending the cliff at its rear, we come upon the brink of a much more extensive terrace-plain which is also backed by apparent sea-cliffs. The front of this terrace has an elevation of 460 feet, and its rear 497 feet with a slope of 37 feet in about a half a mile. When viewed on a level the plain presents a uniform, apparently flat surface. Immediately that the eye rises above it, however, it is discovered to be pitted over its entire extent by kettle holes which are similar to those noted on the plain below, but which are much larger and relatively to the area much more numerous. In many cases two pits are so close together that the narrow ridge separating them is quite wedge-like and has frequently broken down. The pits are so numerous that it is not practicable to traverse the plain in any direction in a straight line, but only to wind in and out on the narrow remnants of the original plain which are left between the pits. The sides of the pits are in many cases as steep as the material can lie. The material is morainic in character and contains numerous huge boulders. In some cases these large boulders were conspicuous features in the narrow bottoms of the pits. Here again the only suggestion that could be obtained after traversing the plain several times was that the pits were posterior in their origin to that of the plain. Above this remarkable pitted plain is another important terrace also composed of coarse morainic material, but not apparently pitted so far as observations could be made. This terrace is thickly wooded while the lower ground is burned off. On account of the brush it could not be examined easily, but it appeared to slope toward the rocky hillside of the valley, and although this appearance was not verified, it suggested, when taken into connection with the character of the material of which it was composed, the possibility that the feature was a true morainic terrace.*

A definite explanation of the mode of development of these interesting terraces is not possible from the scant study which the writer was able to give them. He can only commend them to students of topographic forms as an interesting field for study which is easily accessible. A tentative suggestion may, however, be not out of place. These terraces occupy the sides of a valley which was unquestionably filled with the continental ice sheet. As the front of the sheet receded this valley was very probably occupied by an ice current running out from the general body of the glacier, or it may possibly have been occupied still later by a local alpine glacier. The configuration of the hills would favor such a possibility. Students of the kettle moraine have come to the conclusion that the kettle-holes of that region have been formed by the burial of masses of ice within the moraine which afterward melted and caused the surface to collapse. There is an immense accumulation of morainic material in the valley we are considering. Is it possible that such accumulations contained numerous buried blocks of ice, which continued frozen until after the high stages of the lake had cut broad terraces out of the moraine? If the high stages of the lake followed closely upon the recession of the ice front, it seems not impossible, when we consider the low temperature which lake Superior maintaines even to this day.

*Series 33.—East side of Thunder Bay.*—The east side of Thunder bay from its upper end to Sawyer's bay presents a very bold and remarkably straight cliff several hundred feet high composed of Keweenian sandstone resting in Animikie slate, both flat bedded and in apparent conformity. The cliff is probably originally and genetically a fault scarp. In the face of the cliff there has been cut a distinct shelf or terrace, the rear of which, at the foot of a talus due largely to sub-aerial degradation, was found to be 57.5 feet (VI). The shelf is assumed to be, in part at least, a wave-cut terrace.

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*cf. Gilbert, Lake Bonneville, p. 81.

A similar terrace is being cut at the present level of the lake, causing the recession of the lower cliff, so that it is apparent that the shelf referred to must have been once wider than it now appears.

*Series 34.—Back of Thunder Cape.*—At the back of Thunder cape, on the south side of the entrance to Sawyer's bay, there has been preserved a series of wave-cut terraces and sea-cliffs which are of unusual interest for the perfection of their form and for the fact that being situated on a projecting portion of the coast they are revealed in sharp and distinct profile to certain points of view. The profile was photographed and is reproduced in plate IX, figure 2, the view selected being that obtained from the north side of Sawyer's bay. All of these terraces have been cut out of Animikie slates and present very sharp sea-cliffs particularly as regards the lower members of the series, where the cliffs are nearly vertical scarps which can only be scaled at certain favorable localities. The timber has been burnt so that their characters are unobscured. The first four of these terraces have a fairly uniform width which does not vary much from 100 feet, and all have the usual lakeward slope. The figures obtained for the elevations of these, at the base of their limiting sea-cliffs, are respectively 49.6 feet (V), 122 feet (XI), 170 feet (XV) and 261.2 feet (XX). The fifth terrace is smaller and has an elevation of 288.4 feet (XXI). The sixth terrace breaks down in its front part into a broad uneven plain when examined closely, but when viewed from a distance affords the simple profile of a continuous slope. Its altitude is 392.3 feet (XXV). Above this there is still another broad terrace, the rear of which was found to be at a point representing its sharpest features, 482.2 feet. This terrace slopes, however, rather rapidly, is more obscured by timber and could not be definitely recognized as of wave-wrought origin. It was therefore not placed in the table although there is a probability of its being a strand line. At its rear is a talus accumulation from cliffs of trap rock which rise high above it.

*Series 35.—Silver Islet.*—On the trail from the deserted village at Silver islet to lake Marie Louise an interesting series of beaches may be conveniently examined. The series is chiefly interesting for the great number of beaches which are found within a very limited vertical range. The crest of the present storm beach is 12 feet above the level of the lake. Between this and a beach the crest of which is 39.3 feet above the lake, there are no less than nine distinct well formed shingle beach ridges rising one above another on a gentle slope. The first two of these are somewhat larger and apparently of more importance than the others and are placed in the table at stages II and III, the elevation of their respective crests being 14.7 feet and 20.5 feet. The elevations obtained for the crests of the other shingle ridges are as follows: 21.4 feet, 23.2 feet, 25.9 feet, 26.7 feet, 31 feet, 33.7 feet, and 36.8 feet. If projected on a vertical plane these beaches, eleven in all, would appear closely crowded, but in reality, owing to the gentle slope upon which they have been built, they are spaced horizontally so as to be well individualized and spread over several hundred yards of ground in a direction transverse to their trend.

This portion of the series, only certain dominant members of which have been inserted in the table, clearly indicates a gradual recession of the lake, from the stage at which the 39.3 feet (IV) beach was built down to the present level.

At this level the beaches cease and the next indication of a strand line is a terrace at 59.2 feet (VI) with a low and rather ill-defined cliff at its rear. The next is an isolated beach resting on a rocky slope the crest of which is 89.2 feet (VIII) above the lake on the line of the trail. In ascending the trail we next come upon a beach at 136.7 feet (XII) which is the lowest of a continuous succession of beaches extending for a distance of about 600 feet. The highest has along its crest an elevation of 149.2 feet (XIII). This succession of beach ridges has practically the character of a wave-built terrace with this exception, that the stage of the water has not been constant but has been very slightly lower for each successive ridge of the terrace. From the upper beach of this nearly horizontal succession of beach ridges there is another succession which rises more rapidly and which is fewer in number. The upper member of this succession is a beach the crest of which is 168.2 feet (XV). Here then we have evidence of a gradual recession of the lake from stage XV to stage XII or from 168.2 feet to 136.7 feet. The beach which represents stage XV (168.2 feet) is also the highest point of the trail along that portion of it on which strand lines are observable. In other words, the beach is an old bar beach thrown across the mouth of a channel between two portions of the lake, so that after passing over it, we begin to descend over another succession of beaches. These present the same continuity as on the side first approached and our levels showed, that the rolling profile of beach ridges crowded together, continued from the crest at 168.2 feet to 140.8 feet. In this succession there is one prominent beach larger than the rest which has an altitude of 161.4 feet (XIV). Farther along the trail there is a distinct nearly flat terrace at the base of an escarpment of Keweenian rocks, of which two determinations of altitude at points ¼ mile apart, are 115.9 feet and 116 feet (X). Further along the face of the scarp a small terrace was found with an elevation of 127.4 feet (XI). The trail then passes over a remarkable sandy plain which appears to have been once shallow lake bottom. The plain was found to be about 132 feet above the lake but it is somewhat ridged in places and some sand dunes have been raised above its general surface.

*Series 36.—Nipigon.*—At some of the higher stages of lake Superior, lake Nipigon and the great lake into which it now drains by a succession of rapids must have had a common level. The present valley connecting the two bodies of water was always narrow and bounded by precipitate hills of rock, in which, however, there may have been notches affording other outlets than the present one. The channel was particularly narrow just where it would have emerged upon the open lake, being from ¼ to ½ mile wide according to the stage of the water. At one of these higher stages (which one is not definitely known but it was certainly over 200 feet higher than the present) a bar was thrown across the mouth of the channel partially or wholly shutting off the basin of lake Helen from that of lake Superior. This bar formed an immense beach which has been cut through by the Canadian Pacific railway just west of the bridge over the Nipigon river and is used as a gravel-pit so that its structure is well revealed. This great gravel beach is unfortunately covered by a dense jungle which renders its investigation extremely difficult. An attempt was made to ascertain its form and carry a line of levels to its crest. But it was soon realized that it was far from simple in its character and that no safe conclusions could be reached without giving the inquiry much more time than was at our disposal. An apparent crest was reached at an altitude of 198.3 feet, but the impression was obtained that probably the bar had been developed at successive stages of the water on the same general lines, and that the figures obtained afforded no reliable information as to any particular long-continued stage of the lake. But while the strand or strands to which the beach itself corresponds was not definitely ascertained, the slopes of the embankment afforded an excellent opportunity for the registration of lower stages of the water. Upon its slopes there are several very distinct wave or current-cut terraces. Some of these face the open lake and record unequivocally a stage of its waters; others face the channel of the Nipigon river and are due rather to current scouring and therefore strictly of the nature of stream terraces; but being in immediate vicinity of the lake with no drop in surface of the water in the short distance which intervened, they represent also stages of the lake, the figures being a little smaller than the corresponding wave-cut terraces would give.

The highest of these flanking terraces is a broad forest covered plain which in the vicinity of the beach embankment, but not at the rear of the terrace, has an elevation of 131.7 feet (XII). The great breadth of this terrace, its flatness, and the fine sandy material of which it is chiefly composed, indicate that it is not a common shore wave cut or wave built terrace. It is a plain of deposition probably of the character of a delta, and yet it probably represents very closely a level of the lake. A few hundred yards behind Nipigon railway station the front of this broad terrace drops abruptly in the form of a sea-cliff at the base of which a sharp but narrow wave-cut terrace having an elevation of 89.8 feet (VIII). This terrace is traceable around the face of the great bar-beach to the vicinity of the Nipigon bridge. Another determination of its elevation obtained at this place gave the figures 89.9 feet. This narrow terrace in turn drops in a low sea-cliff to the terrace flat on which the railway depot stands and over which the track is laid. At its rear it has an elevation of 82.2 feet (VII).

Crossing the railway track and descending the wagon road to the Hudson Bay Co's. port, we cross three cut terraces having respectively the elevations 61.3 feet (VI), 28.4 feet (IV), and 13 feet (II). In addition to these there is a well marked terrace cut out of the slope of the great bar-beach on the lake Helen side of the railway bridge. This has an elevation of 53.3 feet (V).

*Series 37—Mazokamah*—About half a mile southeast of the mouth of the Mazokamah a high bluff of the Archæan juts out into the lake. On the streamward flank of this bluff there has been revealed by a recent forest fire, a series of remarkably sharp, step-like terraces overlooking Nipigon bay. The terraces, like so many others on this coast, are not cut into the rock, but into an earlier-formed embankment which lies imposed upon the rocky slopes. At the summit of the embankment is a great shingle beach bar at an elevation of 360.6 feet (XXIV) with a lagoon hollow behind it. The origin of this primary embankment is suggested by its proximity to the canon from which Mazokamah river issues. It seems originally to have been an immense embankment which accumulated at the highest stage of the lake registered by the bar referred to. The conditions of coastal topography at this high stage of the water favored such a local accumulation. The stream supplied the boulders, shingle and gravel. The storms distributed them now on this side of the river's discharge and now on that. The portion which was cast to the eastward could not easily recross the mouth of the cañon. Its tendency to move as shore drift far from the point of discharge was effectually checked by the deep water off the jutting shoulder of the bluff. It was, therefore, confined within an open-mouthed bay of smaller extent, and as it accumulated, mantled the rocky slope down into hundreds of feet of water. It is out of this embankment that various later stages of the lake have wrought successive terraces, and at the same time added to its lower slopes. The terraces are generally uniform in character, the widest being about 120 feet and the narrowest about 25 feet, and all are equally sharp. The sea-cliff which rises from the rear of each terrace and extends to the brink of the next higher in the series is, with one exception, of the same character in all cases, and is a straight slope having a declivity somewhat less apparently than the ordinary angle of repose of such material, being probably about 24 degrees. The exception is the cliff between (XVI) 193.1 feet and (XVII) 214.5 feet, which is a rather uneven slope with a much gentler declivity The terraces have thus the character of the wave-cut type, but while this is their essential character it is very probable that at each stage of

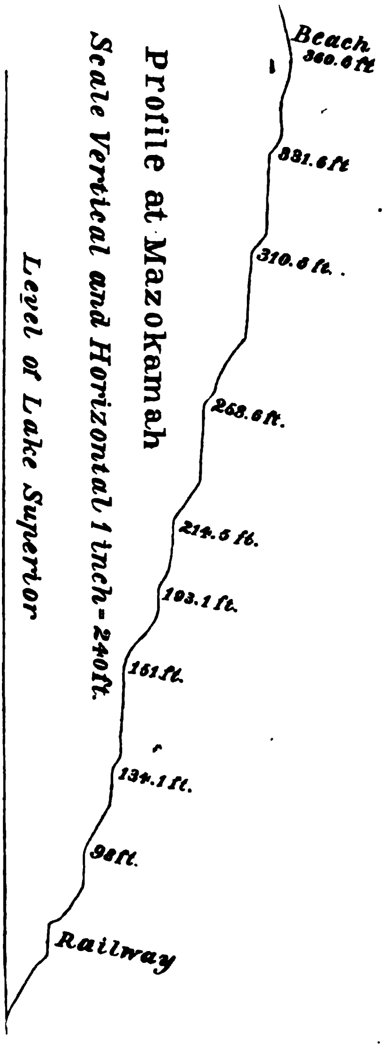


Fig. 11.

the water the Mazokamah river continued to add fresh supplies to the shore drift, so that they are in part also of the character of Gilbert's "cut and build" terrace. The new accessions at each stage being of the same character of material as the embankment in which the cut was being made, it is difficult to distinguish between the cut shelf and its added extension. The vertical distribution of the terrace at this locality is shown in the accompanying diagram. Fig. 11.

*Series 38.—Simpson Island.*—The terraces of the north side of Simpson island are like those at Mazokamah of the wave-cut type. They have about the same lakeward slope and have similar but steeper cliffs rising from their rears. They present a decided contrast, however, to those on the opposite side of the bay at Mazokamah in the paucity of loose material which they exhibit. The terraces being formed on the side of an island there was no contribution of stream and gravel and the shore drift arising from the waste of cliffs was small in amount. The terraces are essentially cut out of the rock of the island and the vigor with which the cutting proceeded is shown in the steep and in some cases nearly vertical declivity of the sea-cliffs behind them. The rock is a sandstone, rather friable in places, with a distinct bedding and southerly dip at low angles. It is protected above by a heavy trap cap. These characters have favored the cutting of the terraces and the cliffs remain much as the shore action left them, having shed but a small amount of talus since the cutting ceased. The fact that the strata dip south while the cliffs face the north precludes the possibility of an unmodified shelf of rock having been mistaken for a

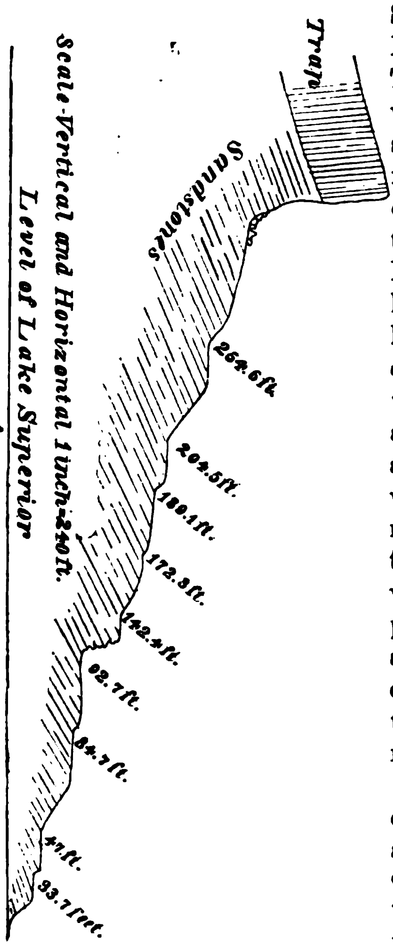
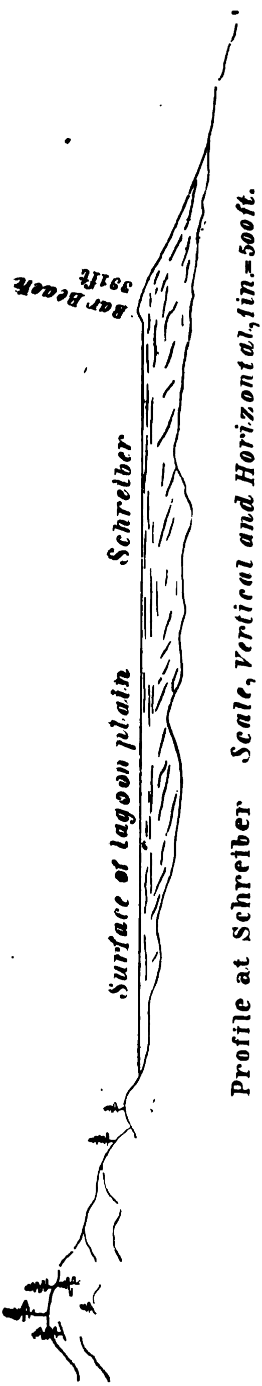


Fig. 12. Profile of north side of Simpson Island.

terrace. The ground has been well burnt of its timber and the terrace slopes are well defined. There is some sandstone and shale-shingle and trap pebbles of local derivation, but these are more abundant on the lower than on the upper terraces so far as the vegetation will permit of observation. The width of the terraces varies from about 25 to 300 feet. The highest terrrace is 254.6 feet above the lake, and at its rear rises a precipice upon which the higher levels have not been registered, or if so, such registration has been obliterated by the undermining action of the Grand Portage stage (XX) of the lake.

*Series 39.—Winston's*—At Winston's siding half way between Rossport and Schreiber is a heavy but quite local accumulation of coarse delta material which has been opened as a gravel pit. The material has been supplied by a small stream which has probably traversed a moraine, as the material is very heterogeneous. The embankment appears to be essentially of the character of delta, spreading out fan-shaped from the mouth of a little canon, but much modified by wave action. Its upper surface in the vicinity of the pit was found to have an elevation of 210 feet (XVII?) The surface is here gently sloping and the maximum hight was not obtained. The general nature of the embankment was not realized when first examined and its altitude measured, and it was only later when viewed at a distance from the lake that its delta character became apparent.

*Series 40.—Schreiber*—The railway shops at Schreiber, a divisional point of the Canadian Pacific railway, and the small town which is growing up around them, occupy a perfectly level piece of land less than a square mile in extent in a region where such level tracts are exceedingly "few and far between." This flat is rudely triangular in shape, one side facing lake Superior, the shore of which is two miles distant. On the other two sides it is bounded by bare or scantily wooded rocky hills which rise irregularly to elevations of a few hundred feet within sight of the railway station. On the northwest side of the flat where it abuts upon the rocky slopes, a small rapid stream from the north has cut a deep sharp gorge down to bedrock showing a thickness of detritus which varies according to the uneven character of the rocky floor, but which probably averages over 100 feet. The rocky ridges which bound the two sides of the flat continue lakeward as bold promontories so that the flat occupies an embayment in the hills. The lakeward boundary of the flat is a beautifully defined beach bar which extends across the embayment from ridge to ridge save where it has been cut through by the stream. The ground has been cleared of the heavy jungle by fire and the characters of the beach bar are not disguised by the thin veil of new growth. The crest of this bar has an altitude of 391 feet above the lake, and on its front it descends rapidly lakeward till it reaches the uneven rocky slope upon which it is imposed. The flat behind it is a filled-in lagoon having a uniform elevation of about three or four feet below the crest of the beach bar. The history of the development of the topographical features thus described cannot be stated in detail from the brief study given to it, but broadly it appears to be as follows: At the higher stages of the lake the stream coming from the hills at the apex of the old embayment dumped its sediment and gravel into the then bay. All but the gravel of the sediment was retained within the bay owing to the deep water off its limiting promontories, and formed a heavy embankment at the bottom of the bay. As this embankment extended lakeward the point of discharge of the stream was apparently carried sufficiently far lakeward to come within the influence of the waves and currents of westerly and southwesterly storms, so that a spit was developed running easterly, which eventually spanned the bay and became a bar. The choking of the first channel of the stream and the filling in to a uniform level of the inclosed lagoon would naturally follow.



Profile at Schreiber Scale, Vertical and Horizontal, 1in.=500ft.

Fig. 13.

Other lower beaches or terraces may possibly be found between this beach bar and the present shore line, but on the trail followed by the writer none were clearly recognized, the country being rough and difficult of inspection.

*Series 41.—Terrace bay.*—Terrace bay has long been noted for its terraces and their character, as ancient strands of lake Superior were recognized as early as 1847.*

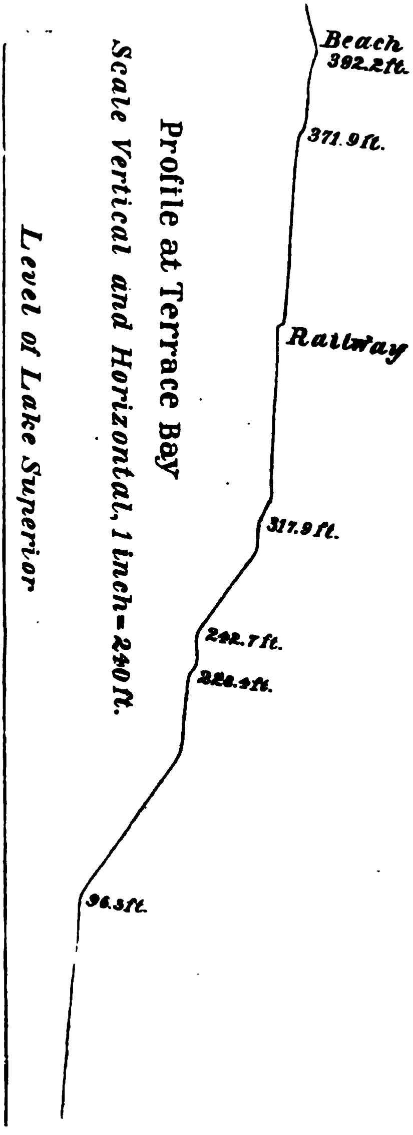


Fig. 14.

The embayment occupied by Terrace bay is rudely horseshoe-shaped and the hills rise steeply above the bay in a succession of great terrace steps, like a magnificent amphitheatre. These terraces are ideal in their perfection of form, free of timber for the most part, and as sharp in their profile as if they had been constructed of masonry. The embayment seems to have been originally occupied by an immense embankment which spanned the valley, the abundance of the material being due doubtless to the proximity of the early representative of the Black river, which now enters lake Superior a little to the east of Terrace bay. The top of this embankment is a broad well-rounded beach, the crest of which is 392.2 feet (XXV) above the lake. It evidently was a bar beach which separated a deep lagoon from the open lake. It is on the front of this embankment that the terraces have been constructed.

The material of the embankment is unconsolidated gravel andpebbles, and the cliffs at the rear of each terrace have the angle of repose of such material, viz., uniformly 34° by measurement. The width of the terrace varies from 1,000 feet to 50 feet. The series is so simple in its general character that no farther description is necessary. A profile plotted from measurements is given, which it is hoped, will afford some idea of the distinctness of the terraces. The elevations obtained for the rear part of the different terraces are as follows: 96.3 feet (IX), 228.4 feet (XVIII), 242.7 feet (XIX), 317.9 feet (XXII), 371.5 feet (XXIV). The impression which an inspection of the series gives is that, having been developed at different and distinct stages of the water, the subsidence of the lake must have been by great leaps from the level of one terrace to that of the next below. This notion is, however, at once corrected, when it is remembered that the development of one terrace may involve the destruction of many or all of the earlier formed terraces or benches. The number of the terraces is, therefore, no indication whatever of the number of distinct and long-continued stages of the lake. These terraces are essentially wave-cut terraces, but as the supply of material for construction doubtless continued at all stages, to some extent at least, they may in part be current-built terraces. And as the material from the cliffs in process of recession would be the same as the shore drift supplied by neighboring streams, there would be no observable difference between the portion of the terrace which is cut and that which is added to it, and there would be no break in the profile.

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*Logan—Report of Progress. Geological Survey of Canada.

*Series 42.—Jackfish Bay.*—On the east side of Jackfish bay, just south of Jackfish station on the Canadian Pacific railway, there is an embayment in the hills which is now spanned by a railway embankment, which, at its highest part, is about 85 feet above the lake. The upper part of this embayment was, at the highest stage of the lake of which there is here a record, the seat of the accumulation of an immense embankment. The surface of the embankment is apparently flat and no rise could be detected with the spirit level for a distance of an eighth of a mile. It passes under the timber and its full extent was not determined. It appears to be a delta plain of a drainage system which found other outlets as the waters of the lake fell to lower stages. The elevation of this delta plain was found to be 418.3 feet. (XXVI) On the front steep slope of the delta there have been carved two very distinct terraces, both with well-defined steeply sloping sea-cliffs remarkably uniform and intact. The first of these in descending order is about 100 feet wide and at the base of its sea-cliff has an altitude of 391.3 feet (XXV). The second terrace is smaller but no less distinct. Its elevation is 367.2 feet (XXIV). Below the front of this terrace the profile of the surface changes from the step-like character given to it by the terraces to a gentle slope extending to the present shore about a mile distant. On this slope, on which the underlying rock may in places be seen protruding, a great many shingle and gravel beaches have been thrown up at different stages of the lake; and we have here perhaps the fullest representation of the ancient strand lines of the lake that is to be found anywhere on this coast.

The first five of these beaches are distinct from one another being well spaced both vertically and horizontally. Their individuality is no less marked than their general perfection of form, size, and continuity. They are concave lakeward and usually have a distinct depression behind them. The country has been burnt and they are easy of access for purposes of examination.

The figures obtained by our leveling for the crests of these five beaches is as follows: 317.2 feet (XXII), 259.2 feet (XX), 237.9 feet (XIX), 228.5 feet (XVIII), and 175.6 feet (XV). . About 6 feet above the last (XV) there is a beach-like ridge which may also be indicative of a distinct stage of the water, but was thought to be a feature of practically the same shore as that at which beach XV was developed. On the lower slope of beach XV there is a narrow terrace which appears to be cut into the higher embankment at an elevation of 157.9 feet (XIII). The ground is somewhat obscure at this place and the fact that it was really a cut terrace and not the incipient form of a wave-built terrace was not clearly established. Continuing down the slope there are well defined and distinctly spaced beaches at elevations for which we obtained the following figures, viz: 135.9 feet (XII.), 127.7 feet (XI an exceptionally large beach), and 119.5 feet (X).

These are followed by a continuous succession of rolling beaches, the highest of which has an elevation of 110.1 feet and the lowest 84.9 feet; of this succession the most prominent are the last mentioned and one at 102.9 feet which are placed in the table as strand lines (VII) and (IX); between these two for a distance of 1200 yards one beach follows another closely. An inspection of the ground leaves little doubt in the mind of the observer but that there was a gradual and comparatively regular recession of the waters of the lake from the stage corresponding to the 110.1 foot beach to that at which the 84.9 foot beach was formed. On the lakeward side of the railway embankment we find another rolling succession of beaches, the figures for the crests of which are as follows: 57.1 feet (VI), 53.8 feet, 51 feet and 46.2 feet (V). These follow one another closely and again indicate a lowering of the water by easy stages. Separated from these by an interval are two lower beaches quite distinct from each other. The first is an embankment of great size at 33.5 feet (IV); and the second is less prominent and has an elevation of 19.2 feet (III). The lowest record is that of a small wave-built terrace 9.8 feet high, the product of the waves of the present stage of the lake and which is an abandoned terrace only as regards its rear portion. Its front is still growing. It is a significant fact that the only horrizontal wave-built terrace in this very full record of shore lines is that of the present strand and suggests that the present stage has been perhaps the most enduring of the many through which the lake has passed. Where conditions for the development of shingle and gravel beaches have been so favorable, it is remarkable that no single stage of the lake should have lasted long enough for the construction of the characteristically rigid wave-built terraces which are seen at some places along the present shore.

*Series 43—Three miles east of Jackfish.*—Just around the rocky point which defines the limit of Jackfish bay and about three miles or less from Jackfish station may be seen another fine series of strand lines which present a strong contrast to those last described. We have seen that in series 42 the conditions of the embayment favored the growth of beaches and that with the exception of two terraces near the top of the series there are practically no well defined wave-cut terraces. In series 43 just around a jutting ridge of rock which separates the two embayments, we have a fairly full series of strand lines in which there is not a single beach, the whole series being composed of terraces. The embankment in which they are cut is an extensive one in which a large gravel pit has been opened for the railway. Its upper surface is quite flat, so far as could be observed and its entire extent was not investigated. It appears in places to abut sharply against projecting portions of the rocky ridge. It appears to be analogous to the embankment at the head of the Jackfish embayment of series 42. Its elevation is 212.9 feet (XVII). The front of this terrace is limited by the sea-cliff of a lower terrace which has an elevation of 174.5 feet (XV). This terrace is very narrow owing to the recession of the sea-cliff of the next lower terrace which is that upon which the railway track lies. This has a maximum elevation of 111 feet, but the precise rear of the terrace is not susceptible of exact determination, and this figure (111 feet) was considered in the field several feet too high for what is probably the true rear of the terrace. Below this are four well defined cut terraces having the following altitudes, viz: 59.2 feet (VI), 47.3 feet (V), 40 feet (IV) and 16 feet (III). Below this is a great beach which appears to be yet within reach of exceptional storms although its crest is 13.3 feet high. By an error it appears in the table as strand line II.

*Series 44.—Dog River.*—To the east of the Dog river we have a set of conditions somewhat analogous to those at Terrace bay. At a very early date Dog river was a source of supply for a great mass of shore drift. The prevailing storms have thrown it all to the east side of the river, where at a high level of the lake it accumulated in a great embankment. On the summit of this embankment at a point about three miles east of the mouth of Dog river, a beach was thrown up which separated a shallow lagoon from the open lake. Below this beach on the front of the embankment there have been cut numerous terraces which are well preserved and perfect in form. The crest of the summit beach is 323.4 feet (XXIII). The following elevations were obtained for the rear part of the various terraces in descending order: 314.7 feet (XXII), 255.4 feet (XX), 215.6 feet (XVII), 100.7 feet (IX), 39.7 feet (IV), 16.5 feet (III). A very interesting feature of this series is that the actual process of their development may be observed in progress at the present shore. The cliffs are there actively receding and have a declivity which is the angle of repose of the gravel and sand of which the primary embankment is composed. The recession has gone so far that for a considerable distance the 16.5 foot terrace has been entirely obliterated save at points where it is protected from undermining by a projecting basement of hard rock. A broad sub-aqueous terrace of very gentle slope is being formed and the waves which traverse this shallow shelf being feeble at the shore line, the rear of the terrace where it abuts upon its sea cliff is precisely the level of the lake.

*Series 45.—Sand River.*—On the south side of the Sand river about a quarter of a mile from its mouth are two terraces the lower of which is very distinct while the upper is somewhat indefinite and hard to recognize on account of large numbers of huge boulders which cumber it. The terraces are composed mostly of boulders and large pebbles brought down by the stream. They flank the rocky walls of the canon in which the stream flows, but their position is clearly conditioned by a former level of the lake, the stream having cut through them as the lake subsided. The levels obtained for these terraces are 75.2 feet (VII) and 118 feet (X).

*Series 46.—Montreal River*—The Montreal river in its lower stretch is a torrent rushing through a very narrow, high-walled canon whose form is due to structural planes in the granite of the country. This torrent has brought down to the lake a large

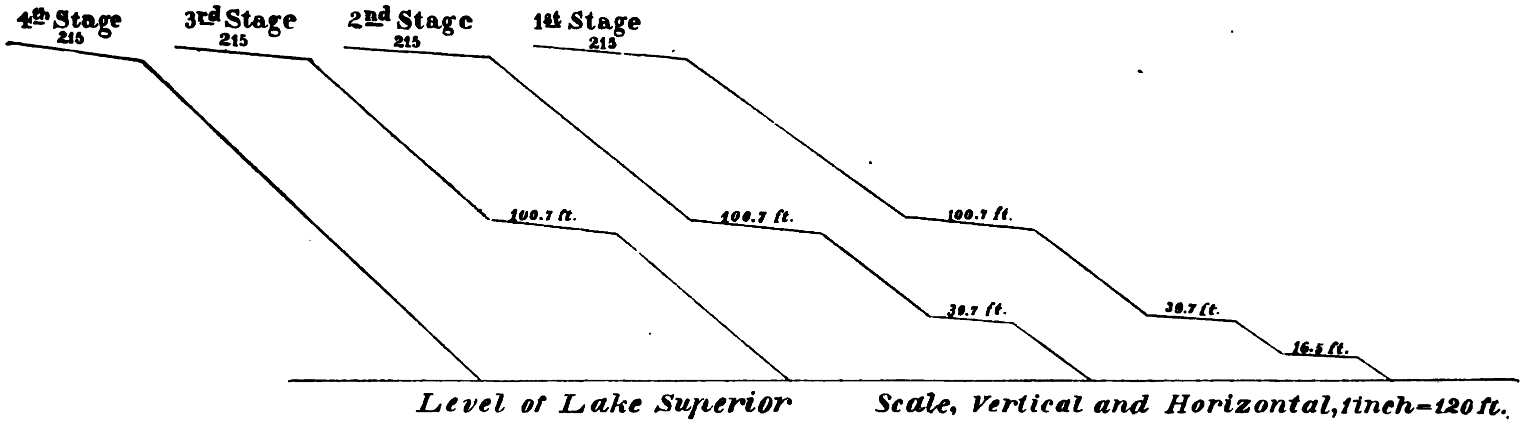


Diagram illustrating obliteration of Terraces east of Dog River

*1st Stage shows four actual Terraces.*
*In the 2nd stage the sea cliff of the present shore has receded till it coincides with the sea cliff of the 16.5 ft. terrace.*
*In the 3rd stage the same sea cliff has receded till it coincides with that of the 39.7 ft. terrace. In the 4th stage 3 of the four terraces have been obliterated.*

Fig. 15.

amount of very coarse material which has been dumped at the mouth of the canon and spread out in the form of a delta. The surface material of the delta consists chiefly of large boulders and angular blocks whose average diameter is perhaps three feet at the mouth of the canon, with masses of less size down to cobble stones farther lakeward. The finer gravel has been carried to the outer edge of the delta and there thrown up into a magnificent beach through which the stream maintains a narrow passage to the lake. This fine bar has its counterpart for an older phase of the stream at an elevation of 211.3 feet (XVII) less than half a mile up the canon and above the edge of its more precipitous part. The bar has the form of a great beach extending across the valley and although covered with timber is easily recognized by its form and by the material of which it is built. This bar beach forms the crest of a great embankment probably much the same in character as that accumulating at the mouth of the present stream. On the front slope of this embankment there have been developed four sharply marked terraces. The upper two of these have elevations of 134.8 feet (XII) and 78.7 feet (VII), respectively, the first being over 100 feet wide and the second not more than 25 feet. Both appear to be essentially wave-cut terraces and have sea-cliffs as steep as the material of which the primary embankment is composed will lie. The lower two terraces have elevations of 61.9 feet (VI) and 45.2 feet (V) and are the surfaces of former deltas which have been cut through by the lowering of the base level. Their proximity to the open lake and their position below the precipitous narrow part of the canon make it clear that their elevation is approximately that of the lake at the stage at which their rear part was built. They have no true sea-cliffs, and they lie below the level of rocky surface upon which the higher embankment with its secondary terraces rests.

*Series 47.—Mamainse.*—At the deserted mining village of Mamainse three of the ancient shore lines of the lake may be recognized by the usual characteristic features. The lowest of these is a gravel and shingle beach which skirts the back of the old stamp mill. Its crest, where crossed by our levels, is 122.1 feet (XI). The second is a distinct terrace which at its rear was found to be 156.8 feet (XIII). The third is also a terrace, but a somewhat extensive one, the rear of which was not observed. It is an apparently flat gravel plain, thickly timbered, the surface of which, near its brink, is 191 feet above the lake (XVI).

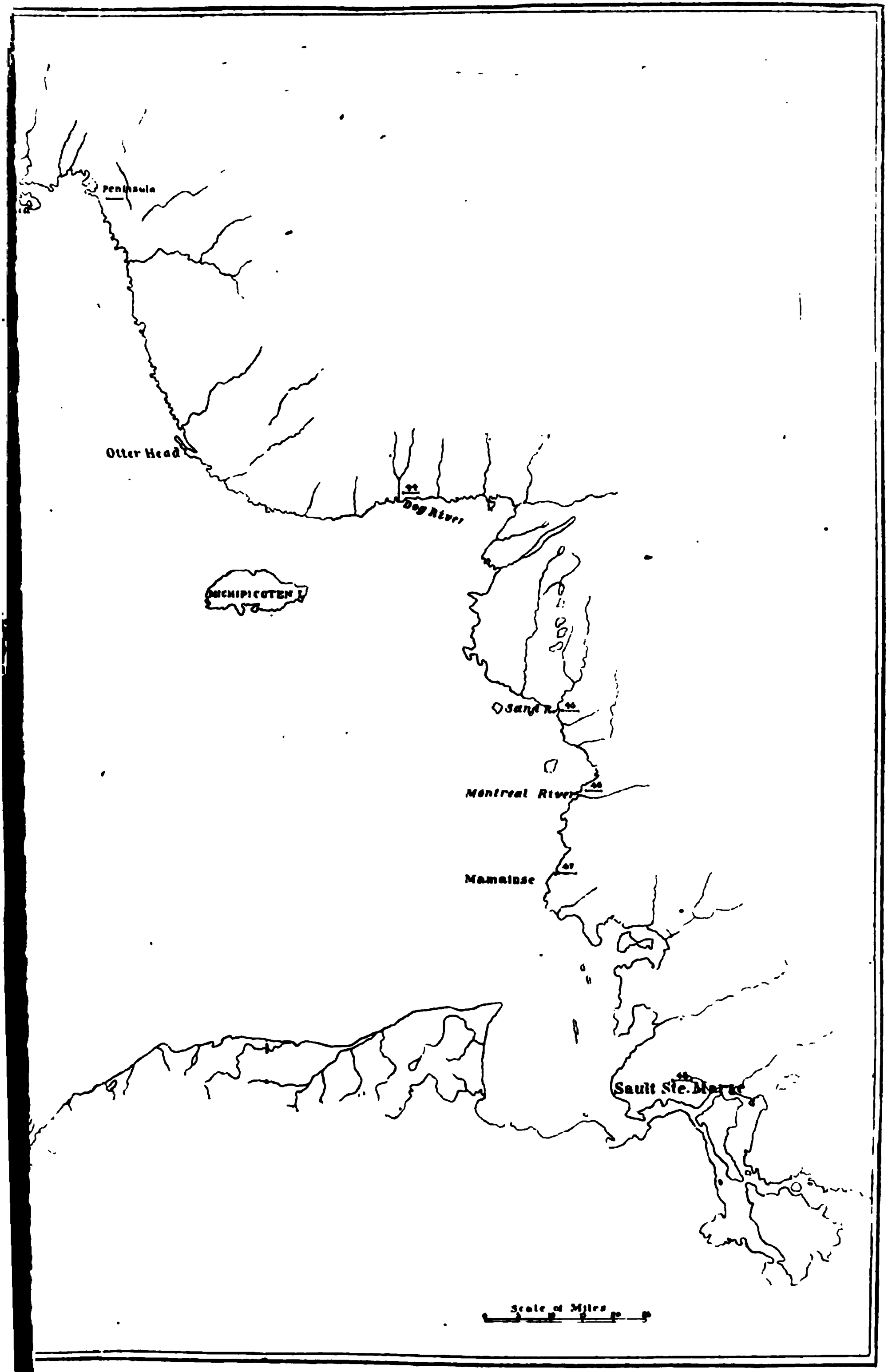
*Series 48.—Sault Ste. Marie.*—The last of our series of the ancient strand lines of lake Superior is in the vicinity of the present outlet of the lake, and is interesting for its geographical position between lakes Superior and Huron; for the high levels at which the strand lines are observable and for their well-preserved and unequivocal character. The terracing of the hills on the north side of the St. Mary's river is a conspicuous figure of the topography and may be readily examined at many points. The town of Sault Ste. Marie, in Ontario, is, like Port Arthur, built upon terraces. Of those within the town, two are very prominent, and there are suggestions of others. Only the lower of these two terraces has its sea-cliff (possibly stream cliff) within the town limits. The base of the cliff is just north of the line of the Canadian Pacific railway track, and on Pim street, where our levels were run, the rear of the terrace was found to be 49 feet above lake Superior (V). The cliff rises steeply and is composed chiefly of clayey material. The second terrace which extends back from the upper edge of the cliff, is a broad plain, at least a mile in width, and does not appear to have a well-defined cliff at its rear, but to have a sinuous abutment upon a series of low tumultuous hills composed of morainic drift. The altitude of this broad terrace at its rear was not precisely determined although our levels crossed it, but it is probably about 150 feet. These two terraces are distinct from the remaining members of the series which are grouped together farther back on the front part of the hills. They are probably best seen on the Tarentorus road, about four miles from the town of Sault Ste. Marie. Here an immense embankment has been accumulated along the front of the hills in the embayment now occupied by the Root river, which has since cut a deep canon through it. This embankment culminates in a great gravel and shingle beach, the crest of which is 413.9 feet above the lake (XXVI). Immediately below this there is a rolling succession of three benches for which the following elevations were obtained: 403.3 feet, 404.8 feet, and 400.4 feet, the succession indicating a stage of the water somewhat lower than XXVI at which there was a tendency to form a wave-built terrace with a gradually subsiding lake. A few hundred feet down the road we come upon a good terrace, the rear of which is 365.3 feet above the lake (XXIV). On the front part of the terrace is a distinct but low beach, two feet lower than the rear of the terrace. The road then drops to the level of another terrace which is several hundred yards wide and which has an altitude at its rear, where it encircles an island-like mass of rock that projects through it, of 311.2 feet

(XXII). The front of this terrace is the front of the primary embankment of shore drift and there are cut into its steep slope four wave-cut terraces ranging from ten to fifty feet in width, all well defined. The elevations obtained for these, in descending order are, 223.9 feet, (XVIII), 207.6 feet (XVII), 174.4 feet (XV), and 150 feet (XIII).

## DISCUSSION OF RESULTS.

The facts set forth in the preceding pages, regarding the hypsometric and geographic distribution of the observed abandoned strands on the coast of lake Superior, suggest many interesting problems which cannot be here entered upon. The information which has been won is but a contribution to an inquiry into a very important chapter in the recent physiographic development of North America. The full inquiry will require the labor of many investigators through many years before entirely satisfactory and invulnerable conclusions are attained. A few preliminary inferences and suggestions, arising from a consideration of the data which has been presented, may here, however, be discussed briefly.

Up to the present point the abandoned strands with which we are concerned in this inquiry have been discussed as topographic features of the *coast* of lake Superior, and they have been alluded to as having been developed at the higher stages of that lake. But a little reflection will make it clear that all but the very lowest of these strands represent stages of a sheet of water which was very different in its general physiography from the present lake Superior. It was many times more extensive than lake Superior, and covered the entire region of the great lakes Huron and Michigan with several hundred feet of water. The extent of this vast lake was probably at least twice as great as the combined areas of the present lakes Superior, Michigan and Huron, or about 150,000 square miles; and these lakes are but the remnants of its waters gathered together in the subordinate depressions of the once greater basin. The Algonquin beach which skirts the coast of lake Huron marks but an episode in the later stages of subsidence of this remarkable sheet of fresh water. For such a lake it would be manifestly incongruous to retain the name lake Superior, and confusion would constantly arise by such a usuage. It is, in fact, scarcely possible to discuss the problems presented without some distinctive name for the immense lake which played so important a rôle in the post-glacial physiography of the continent, and of


Peninsula
Otter Head
Dog River
Michipicoten I.
Sand R.
46
Montreal River
46
Mamainse
47
Sault Ste. Marie
Scale of Miles

which the present great lakes are but residual parts. The necessity for such a convenient designation has been anticipated by Spencer, who has suggested for this great lake the name LAKE WARREN.*

By lake Warren, then, will be understood the great sheet of water along whose successive shores were developed the terraces and beaches now apparent on the north coast of lake Superior; and the name will be applicable to this lake from its highest stages down to that stage when its waters became definitely segregated into the different subordinate depressions, and assumed the characters of the present great lakes. The different shore lines of lake Warren may, of course, receive special designations without in any way interfering with the name of the lake itself.

A glance at the table shows that in different parts of the coast of lake Superior the number of observable strand lines varies from one to nineteen; while along very considerable portions of the coast none can be detected. This great discrepancy in the records of the different distinct stages at which the waters of the lake Warren have stood is to be accounted for in different ways. Of course a very large proportion of the discrepancy is only apparent, and is due to the fact that the coast is a timbered country. Were the coastal slope stripped of its timber many of the local series of strand lines would have a much fuller representation than is shown in the table. And in this respect forest fires are coming rapidly to the assistance of the inquiring geologist. If fire continues its destructive work in the future as vigorously as in the past few decades, the record of ancient beaches and terraces will in many places be much fuller than is here given. But apart from gaps in the series due to obscuration of the topography by timber, there are many localities where the topography is well exposed, and all the beaches and terraces present may be accurately determined; and on comparing these with one another very serious differences are at once apparent, even when the localities are not widely separated. These may be due to one or another of two causes. (1) The coastal slope is not equally susceptible of receiving the registration of shore lines at different levels. One portion of the slope may be admirably adapted to the formation of sea-cliffs and embankments, while another portion either above or below may not lend itself to the development of such features. This difference in susceptibility of receiving shore line impressions is due partly to the varying character of the rocks and partly to the general steepness of the coastal slope. (2) A second cause of the lack of concordance between the different series of shore features is that many of them, particularly those which take the form of terraces in preexisting embankments, have been obliterated by wave action operating at lower levels than that at which they were formed, by the process described as now in operation near Dog river.

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*Trans. Roy. Soc. Can., Sec. IV, 1889, p. 122.

There is, however, still another important possibility to be considered. There may have been differential movements within the limits of the present lake Superior basin when its outlet was relatively higher than at present. There are two general cases under such a supposition: (1) the differential movement may have been of such a character that a portion of the coast did not change its altitude relatively to the outlet, while another portion did so change; or (2) the entire coast, within the limits named, may have changed its altitude relatively to the outlet, or become inclined. In the first case one shore line in one part of the coast would correspond to more than one shore line in another part, *i. e.*, there would not be in all parts of the coast the same number of abandoned strand lines even if the record were quite complete. But the supposition is a violent one, involving post-glacial faulting or flexure of which there is no evidence whatever. In the second case there would be an equal number of strand lines in all parts of the coast (supposing none were re-submerged) but all would converge upon the outlet if projected on a vertical plane.

In both cases the vertical interval between the same pairs of strand lines in all different parts of the coast would not be constant Moreover, it would be by the merest chance that in the second case the same figures would be obtained for the vertical interval between strand lines in different parts of the coast. If it can be shown that, notwithstanding the actual discrepancies in the different local series, there is a prevailing constancy of interval between strand lines in different localities, we shall not be warranted in assuming that the discrepancies apparent in the table are due to local move mentsat a time when the basin was fuller than now. To be convinced that there is a prevailing constancy of interval one has only to study the table of elevations, bearing in mind the fact, that the elevations given of the ancient shore features of lake Warren may differ a varying number of feet (ordinarily up to ten feet) from the actual water level at which they were formed. In the table will be found many striking coincidences of vertical interval; and the nature of the problem is such, that positive evidence of this character is important, while negative evidence is practically valueless, owing to the fact many conditions may cause apparent discrepancies, while only one set of conditions would favor a constancy of vertical interval between the abandoned strands, viz., *a uniform subsidence of the water along the entire extent of the coast.* Not only is there a prevailing constancy of interval between the abandoned strands, suggesting the correlation implied in the table, but when we compare the intervals between the strands of the various local series and the present level of the lake there is a far more imposing array of coincidences. This becomes apparent in the following table, in the consideration of which it must be again remembered that, if the same features were to be subjected to the same kind of measurement, there would be a maximum discrepancy for the present level of the lake of 15 feet. In addition to this there are possible errors of observation and instrumental errors to be taken into account; so that the maximum discrepancies in the following table are very moderate in extent.

### TABLE

Showing the extent of coincidence of the vertical intervals between the level of lake Superior and some of the abandoned strands of lake Warren at various well distributed localities on the coast.

| Number of localities. | Maximum and minimum values of the interval in feet. | Maximum discrepancy in feet. |
|---|---|---|
| 7 | 17.6- 12.1 | 5.5 |
| 11 | 21.7- 16.0 | 5.7 |
| 17 | 40 0- 27.2 | 12.8 |
| 18 | 53.3- 43.0 | 10.3 |
| 10 | 61.9- 55.9 | 6.0 |
| 18 | 86.8- 74.4 | 12.2 |
| 5 | 92.7- 89.2 | 3.5 |
| 12 | 106.3- 97.0 | 9.3 |
| 9 | 119.5-113.5 | 6.0 |
| 9 | 129.2-122.0 | 7.2 |
| 10 | 142.4-134.1 | 8.3 |
| 6 | 157.9-148.8 | 9.1 |
| 4 | 162.6-160.5 | 2.1 |
| 8 | 175.6-170.0 | 5.6 |
| 3 | 193.1-189.1 | 4.0 |
| 7 | 215.6-204.5 | 11.1 |
| 7 | 231 8-221.8 | 10.0 |
| 2 | 142.7-237.9 | 4.8 |
| 7 | 261.2-253 6 | 7.6 |
| 3 | 288.4-278.9 | 9.5 |
| 7 | 313.9-310.6 | 3.3 |
| 3 | 331.6-323.4 | 8.2 |
| 4 | 371.5-360.6 | 10.9 |
| 4 | 392 3-391.0 | 1.3 |
| 2 | 418.3-413.9 | 3.4 |
| 2 | 439.7-436.2 | 3.5 |
| 3 | 475 9-473.0 | 2.9 |
| 2 | 509.5-509.5 | 0.0 |
| 2 | 534.8-534.0 | 0.8 |

This remarkable coincidence of vertical interval could not be a matter of accident, and it seems to the writer to warrant the correlation of the abandoned strands of the lake as expressed in the table. But if this be granted it also demonstrates another important fact: viz., The lack of local deformation in the strand lines since their abandonment by the subsiding waters of the lake. For it is clear, that if the strands are to be correlated as indicated in the table, they are as perfectly horizontal as when they were functional shores. And in this statement we have a satisfactory, even if unexpected, answer to the question proposed at the outset of the investigation.

It follows from this conclusion, that every distinct altitude occupied anywhere on the coast by a strand line represents a stage of lake Warren. In other words, the total number of observed strands marks the minimum number of distinct stages. There are recorded in the table 33 strands having distinct altitudes. With reference to one of these (XXVIII) there is some doubt as to its representing a stage distinct from one recorded at a lower level. Thus there have been in the history of the recession of the lake at least 32 definite stages. The maximum number recognized in any one locality is 19, so that the minimum defect in the record in the most favored locality is 13, i. e. in the most complete series only 60 per cent. of the minimum complement of shore lines is represented.

So far as can be inferred from a consideration of the observed strand lines, the subsidence of the lake may have been effected by a gradual lowering of the waters, with a definite halt at each of the stages represented by a strand line in the topography of the coast; or the waters may have dropped rapidly from one stage to another. The latter assumption for so large a sheet of water involves so much violence that it is naturally repugnant to the geological mind. The only probable condition which would give rise to a rapid drop in the water of the lake would be the rupture of an ice dam. But, as will be urged in the sequel, ice barriers appear to be ruled out of the problem. Conditions favoring the rapid trenching of soft material, such as morainic débris, producing effects similar to the rapid lowering of lake Bonneville, are possible; but in the utter absence of evidence of such action this possibility can scarcely be entertained at present. It seems probable, then, that the lowering of the water has been gradual. But while this is so it does not imply that the subsidence was uniformly gradual; the occurrence of successions of beaches following one another closely on certain of the lower portions of the coastal slope (as has been indicated in earlier pages of this paper) seems to mark a much more gradual subsidence within certain limits of elevation than that which usually obtained. On the other hand, the wide vertical gaps between the strand lines in the higher parts of the coast may indicate a more rapid lowering of the water, or at least less frequent stoppages of the process of subsidence. But owing to the imperfection of the record the evidence is at best only suggestive on this point.

There can be little question but that every one of the many stages of lake Warren had its level determined by a definite outlet, just as the level of lake Superior is conditioned by the overflow at Sault Ste. Marie. The existence of post-glacial beaches and terraces at high levels in the vicinity of Sault Ste. Marie, demonstrates clearly that no ice barrier, spanning the interval between the high ground on the north side of the lake and that on the south side, can be invoked to explain the high level strand lines of the north coast as those of a body of water dammed back by a glacier lobe, and corresponding in geographical extent approximately with the present lake Superior. It was a sheet of water of much vaster proportions; and for such it is entirely reasonable to suppose that epeirogenic movements may have been in progress in one portion of its area and not in others; or that a movement of uniform elevation or depression in one part may have proceeded contemporaneously with local warping in another. Further, since the supposition of an ice barrier at Sault Ste. Marie is out of the question, and since there is no known single gorge of post-glacial age which, by being progressively trenched, would, without crustal warping, account for the lowering of the waters through a range of 600 feet, we seem, so far as our present knowledge serves us, to be forced to assume crustal deformation as the primary means of the lowering of the outlet of the lake. A consideration of the abandoned strand lines of the north coast of lake Superior warrants the conclusion that whatever deformation may have been in progress, the region examined was not locally warped, although it may have been uniformly uplifted or depressed. Thus it seems probable that local warping of the crust, in some region far removed from lake Superior, is accountable for the lowering of the land barrier which held back the waters of lake Warren. The region in which evidence of such changes should be looked for lies to the south and southeast of lakes Michigan and Huron; and the movements which here concern us are probably closely related to those revealed in the warping of the Iroquois and Algonquin shore lines, as described by Gilbert and Spencer. These warpings, however, must represent a late movement in the general process; since the scoring of the Algonquin beach of Spencer is probably only a recent episode in the subsidence of the great sheet of water which embraced all three of the upper lakes.

The general epeirogenic result of the movements which lowered the southern and southeastern barrier of the basin of lake Warren, and caused the registration of the great succession of strand lines now observable on the north coast of lake Superior, seems to have been an absolute and uniform elevation of a large portion of central Canada, including the region about lake Superior, of several hundred feet, and a relative, and probably also an absolute, depression of the region south of the present lakes, embracing the states of Ohio and Indiana. For on the north side of the divide between lake Superior and Hudson's bay, at a distance from lake Superior of from 150 to 200 miles, post-glacial marine deposits occur on Kenogami river at an elevation of 450 feet above the sea, extending thence continuously to the shore of James' bay; and similar post-glacial marine deposits occur on the Missinibi river at an elevation of 300 feet.* Since the occupancy by the sea of these regions north of the divide and the high stages of lake Warren are both clearly post-glacial, we would seem to be warranted in correlating the two events; and also in further correlating the gradual subsidence of lake Warren with the emergence of the Hudson's bay slope from beneath the sea.

If the general supposition be true, that the draining of lake Warren was due to the relative lowering of a land barrier far southeast of the present lake Superior, it seems probable farther that the outlet of this vast sheet of water shifted from time to time in consequence of the continental warping. It would be quite reasonable, also, to suppose that if a southerly land barrier conditioned the high levels of lake Warren, the same barrier may have been high enough at first to determime a northerly drainage of the lake to Hudson's bay. The suggestion that such was the case is strengthened by the following interesting circumstance.

The hight-of-land portage south of Long lake, *i. e.*, the divide between the St. Lawrence system of drainage and that of Hudson's bay, is only about 15 miles distant from the shore of lake Superior. The elevation of this pass is 1,102 feet above the sea,† *i. e.*, it is 500 feet above the present level of lake Superior. The description of the pass by Bell leaves little doubt but that it is the abandoned bed of a large river. Now one of the most heavily marked of the abandoned strand lines of the north coast of lake Superior has a precise altitude of 509 feet. The coincidence is a remarkable one, and it is difficult to resist the conclusion that stage XXX of the lake was determined by the altitude of this pass, the drainage being northward. Mr, Upham, if the writer understands him, regards this pass as an outlet for the southerly drainage of a hypothetical lake, dammed back to the north by a wall of ice; but the writer can find no warrant for Mr. Upham's supposition. It is not improbable that the continental ice sheet was still extensive towards the east at the time that lake Warren stood at stage XXX; and it is possible that a lobe of its southern margin may have reached nearly as far south as Sault Ste. Marie. But it had certainly disappeared from the present coast of the northwestern part of the lake and probably had been sufficiently removed from the region northward to permit of the northerly drainage here suggested.

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*Bell, Geol. Survey of Canada, Report of Progress, 1871-72, p. 112, and 1875-76, p. 340.

†Upham, Bull. Geol. Soc. Am., Vol. 2, p 263.

About 50 miles northeast of Michipicoten harbor is another pass, somewhat lower, at an altitude of 440 feet above lake Superior,* at thedivide south of Missinaibi lake. It is possible that this pass may have been blocked with the ice sheet when the Long lake outlet was open, or it may have been blocked with morainic débris which has been since trenched by stream action. If this pass ever served as an outlet of lake Warren it is doubtless to be correlated with stage XXVI which has so strongly marked a strand line at Sault Ste. Marie.

There are other possible outlets concerning which, for lack of information, it is impossible for the writer to speak definitely. It seems not improbable, for instance, that the valley of the St. Croix river served as an outlet for the overflow of some of the high stages of lake Warren, conveying its waters to the Mississippi. The bed of an old channel at the lowest point of the divide between Bois Brulé and St. Croix rivers is described by Upham, who gives the elevation as 468 feet above lake Superior.† This seems to correspond well with strand XXIX of lake Warren, which, at Duluth, has an elevation of about 475 feet. There are possibilities of another outlet to the same general drainage by way of the Illinois river. The Fort Wayne channel doubtless offered another outlet at a different attitude of the surface and a greater absolute elevation than it now has. The Nipissing depression may possibly have been available at some of the higher stages.

Prof. N. H. Winchell, also, has suggested that there is a former outlet by way of Whitefish valley through Little Bay de Noc.‡

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*Upham, op. cit., p. 264.
†Op. cit. p. 258.
‡Am. Jour. Sci., Vol. II. 1871, p. 19.

# VI.

# DIATOMACEÆ OF MINNESOTA INTER-GLACIAL PEAT.

BY BENJAMIN W. THOMAS, F. R. M. S.

WITH A LIST OF SPECIES AND SOME NOTES UPON THEM, BY PROF. HAMILTON L. SMITH, M. A., L. L. D. ALSO DIRECTIONS FOR THE PREPARATION AND MOUNTING OF DIATOMACEÆ. BY DR. CHRISTOPHER JOHNSTON AND PROF. H. L. SMITH.

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Samples of inter-glacial peat from Blue Earth county, Minnesota, sent by Prof. N. H. Winchell, state geologist of Minnesota, were found to be well filled with the siliceous frustules of over 100 different species of fresh water "Diatomaceæ." The stratum of peat from which the specimens were taken was reported as being overlaid by some twenty-two feet of boulder clay, and as resting upon the same material, but I am not advised as to the extent or thickness of the peat in this interesting deposit. The clay both above and below the peat carried many boulders showing glacial striation and on microscopical examination yielded Foraminifera, Radiolaria, and other marine forms peculiar to Minnesota, and some other western boulder clays, but marine forms were not detected in the peat.

Diatomaceæ constitute a group of microscopic organisms of great interest to the student of natural history. They are a family of confervoid algæ of very peculiar character, and the living forms are found in great numbers in almost all waters that are exposed to the sun and air, forming a brown, or yellowish layer at the bottom of the water, adhering to submerged logs and rocks, or attached to the fronds of the larger algæ. Specimens which contain the living diatoms are of course the most valuable for the proper study of their life history, but the plants are so variable in character and habit that it is difficult to give directions that will in all cases give the best results for collecting and preserving them. Collections should be made of plants growing entirely beneath the water, attached to rocks, piers, logs, etc., or to the larger algæ. The slimier the plants appear, if in water free from sand and mud, the richer will be the harvest, as the brown, or yellowish coating upon the algæ and other submerged objects is frequently but a mass of living Diatomaceæ and the moss-like carpeting upon submerged rocks, is often largely made up of beautiful specimens of the filamentous species.

The growing algae, carefully taken from their attachments, can be thoroughly dried, and each collection carefully placed in separate paper boxes, or wrapped in strong, clean paper, and plainly labeled, giving locality, date of collection, etc., or they may be kept moist in phials or small bottles, with a little creosote added to prevent mould, as recommended by Prof. Smith. When prepared either dry or moist as above suggested they can be carefully laid away for future examination, and the dried material can safely be sent to correspondents by mail or otherwise.

But as many of the most carefully collected and promising specimens prove to be of little or no value it is not only desirable but also a most interesting and profitable study to examine them while fresh from the water.

For this purpose with a pipette take a small quantity of sediment from one of the collecting bottles as soon as possible after its collection, and before creosote or other preservative has been added, put a drop from the pipette onto a microscope slide, place a cover glass over it and with a blotter absorb the surplus water. If the collection is of good material the microscope with a one-fourth inch objective will show an abundance of living diatoms, with their rich and beautifully colored endochrome. Some of the frustules will be connected by *stipes* to the larger algæ, some in *tubes*, others in long ribbon-like *filaments*, while many will exhibit those independent and almost intelligent movements that so nearly resemble animal life, and which has caused and is yet causing much discussion among scientists.

The individual cells of the Diatomaceæ containing the protoplastic endochrome are called *frustules* and have an external coating of nearly pure silica, which consists of two portions or *valves*, which are connected at their margins by hoops or bands of variable widths forming a minute box. These siliceous shells or frustules occur in a great variety of beautiful and symmetrical forms, and the valves, or main surfaces of the frustules, are generally richly carved and sculptured, and under the microscope show striæ pinules, ribs, cells, knobs, bosses, etc., in almost innumerable variety and combinations, and some of the species when properly prepared and mounted are the best known tests of the resolving power of microscope objectives. The valves of one well known species that is quite abundant in most of our western waters, the Amphipleura pellucida, show at the rate of 90,000 to 100,000 lines or striæ to the inch.

DIATOMACEÆ are undoubtedly of comparatively recent geological age, and I find no reliable authority of their having been found below the TERTIARY, although unverified claims have recently been made of the finding of their siliceous remains in the coal formations.

The fossil remains of DIATOMACEÆ abound in the vast sub-plutonic and other strata on the Pacific coast of North America, which exhibit both fresh water and marine species, though rarely in a mixed state. In most of the deposits the predominating species present indicate the character of the water, and the climatic influences under which they were accumulated; different species or groups of species, usually appearing in fresh, brackish, or salt water, and in seas, lakes, rivers and marshes.

While a majority of the fossil diatomaceous deposits hitherto discovered are of fresh water origin, by far the most extensive are marine, and some of them spread over large areas. One of the most important stratums of this character in North America is considered as belonging to the Miocene-Tertiary, and is on or near the Atlantic coast, and is largely in the states of New Jersey, Maryland and Virginia. The principal deposits in Maryland commence at about sixteen feet above tide water, and are covered with four to twelve feet of earth. They then dip below tide water until at Fortress Monroe they are from 200 to 400 feet below the surface, and from an artesian well at Atlantic City, N. J., fossil diatomaceous material containing several new and beautiful species has recently been secured from depths respectively of 406, 510, 535, 550 and 628 feet below the surface.

The extent of some deposits of fossil Diatomaceæ and the vast number and variety of forms contained in them, seem almost incredible, and Dr. Buckland states that the remains of these minute forms have added more to the mass of the exterior crust of the globe than has the bones of animals. Ehrenberg estimated that one of the diatomaceous deposits in Bohemia, covering a large area to an average thickness of some fourteen feet, contained not less than 40,000,000,000 diatoms to the cubic inch, and Mr. Frederick Habershaw, several years ago, published a catalogue of over 4,000 species then known to diatomists.

While the samples of inter-glacial peat submitted for examination were all well filled throughout their entire substance with the siliceous remains of fresh water Diatomaceæ, it is not probable that preparations from the small number of specimens at our disposal, and the consequently small number of slides prepared and submitted to Prof. Smith for examination, will be exhaustive as to the diatomaceous contents of the peat. Accumulations of peat and diatoms, like deposits of more nearly pure diatomaceous material, are probably of very slow growth, and, as is well known to microscopists, the upper layers of a stratum often exhibit different species from those found in the lower, or other parts of the same deposit, which may have been accumulated thousands of years earlier, and under different climatic and other influences, and it is quite probable that a more thorough examination of this very interesting deposit will yield many species which were not on the slides submitted for examination, and consequently are not included in the following very valuable "list of species," and the interesting notes upon them, by that veteran diatomist, Prof. H. L. Smith.

Their value and appropriateness in this connection, fully justifies me in using the paper of Dr. Johnston, with the supplement by Prof. Smith, on the "Preparation and Mounting of Diatomaceæ," which originally appeared in "The Lens,' a journal published by "The State Microscopical Society of Illinois," and which is nearly out of print.

## LIST OF SPECIES AND SOME NOTES UPON THEM.

BY PROF. HAMILTON L. SMITH.

The discovery of a peat deposit between two layers of boulder clay in Minnesota, is not only interesting but remarkable, inasmuch as the organisms found in the over and underlying clay are all of marine origin, while those of the deposit, lying between, are not only fresh water forms, similar to those found in the sub-peat deposits of the eastern states, but with one or two exceptions, are forms living at the present time in the great lakes or their tributaries; so that, geologically speaking, the deposit appears to be of very modern origin. While the difference between this and the sub-peat deposits of the eastern states is not very marked, yet a few distinctive species do occur, and will be mentioned in the notes appended to the list, which ally it to the fossil deposits of Oregon, Utah and California, and which, to a practiced eye, would serve to indicate the intermediate position, and to distinguish it from both. How such a deposit, which is certainly of much more recent origin than the boulder clay, came to be thus interposed, is an interesting question,—a question for the geologist to settle. The thickness of the overlying bedvaries from twenty to thirty feet; this, and the lower bed, like theother boulder clays of Minnesota, show, on careful examination, only marine fossils; whereas, as already mentioned, only fresh water and recent forms are found in the peat deposit. At the request of Mr. B. W. Thomas, I have examined a series of slides very carefully prepared by him, and the result will be found in the following list; these are all fresh water diatoms.

The larger diatoms were many of them broken, owing to the character of the deposit, which contained much sand, but the smaller forms were mainly perfect.

The number of species might have been considerably extended if I had followed the example of some of the European diatomists, and affixed *n. sp.* to each form with a slightly varying outline, striation or size. I have in the list, gone to the fullest extent in this direction which I thought allowable; indeed, the number might be somewhat lessened with advantage.

The almost total absence of Surirelleæ Nitzschieæ Pleurosigmæ and Synedreæ, which abound in many eastern deposits, is a characteristic feature, and also the presence in great abundance of spicules of Spongillidæ, and small, flask-shaped bodies; some of these latter are quite smooth and others reticulated or covered with short spines, and all are rigidly siliceous. Ehrenberg classed them with the Infusoria, and even placed them in different families, calling the smooth forms "Trachelomonas," and the hispid or armed ones "Chætotyphila." I have frequently found these in recent gatherings, and they occur quite abundantly in some sub-peat deposits. *e. g.* Wrentham, Mass., and Smithfield, R. I. I give in the list the average length or diameter of the frustules as they occur in this deposit, also references to where figures illustrating the different species may be found, and in the appended notes will be found remarks on most of the species.

HAMILTON L. SMITH.

## DIATOMS FOUND IN INTER-GLACIAL PEAT. MINNESOTA.

| *Length. | Ref. No. | | | Author. | Plate. | Fig. |
|---|---|---|---|---|---|---|
| 10 | 1 | Achnanthidium | flexellum, Breb | Van H | XXVI | 30 |
| 22 | 2 | Amphiprora | ornata, Bailey | Van H | XXII Bis | 5 |
| 12 | 3 | Amphora | ovalis, K. | Van H | I | 1 |
| 40 | 4 | Campylodiscus | clypeus, Ehr | Schmt | LV | 3 |
| 9 | 5 | Cocconeis | lineata, Ehr | Van H | XXX | 32 |
| 5 | 6 | Cyclotella | kutzingiana, Thwaites | Van H | XCIV | 4-6 |
| 25 | 7 | Cymatoplema | hibernica, W. S | S. B. D. | 81 | a |
| 7 | 8 | Cymbella | aequalis, W. S | Schmt | IX | 69 |
| 7 | 9 | Cymbella | affinis, K | Van H | II | 19 |
| 16 | 10 | Cymbella | cistula, Ehr | S. B. D | XXIII | 221-a |
| 17 | 11 | Cymbella | cuspidata, K | S. B. D | II | 22 |
| 17 | 12 | Cymbella | cymbiformis, Ehr. | S. B. D | XXIII | 220 |
| 24 | 13 | Cymbella | ehrenbergii, K | S. B. D | II | 21 |
| 23 | 14 | Cymbella | gastroides, K | Van H. | II | 9 |
| 51 | 15 | Cymbella | lanceolata, Ehr | S. B. D. | XXIII | 219 |
| 8 | 16 | Cymbella | parva, W. S. | S. B. D. | XXIII | 222 |
| 10 | 17 | Cymbella | subaequalis, Green | Van H. | III | 2 |
| 7 | 18 | Denticula | elegans, K. | S. B. D | XLIX | 14-15 |
| 6 | 19 | Denticula | tenuis | S. B. D. | XXXIV | 293 |
| 5 | 20 | Encyonema | caespitosum, K | S. B. D | LV | 346-a |
| 9 | 21 | Encyonema | gracile, Ehr | Van H | III | 20 |
| 22 | 22 | Encyonema | prostratum, Berk | S B. D. | LIV | 345-a |
| 12 | 23 | Encyonema | turgidum, Greg | Van H | III | 12 |
| 7 | 24 | Encyonema | ventricosum, K. | Van H | III | 16 |
| 9 | 25 | Epithemia | alpestris W. S. | S. B. D. | I | 7 |
| 32 | 26 | Epithemia | gibba, K. | Van H | XXXII | 1, 2 |
| 30 | 27 | Epithemia | granulata, K | S. B. D. | I | 3 |
| 8 | 28 | Epithemia | ocellata, K. | S. B. D. | I | 6 a b |
| 14 | 29 | Epithemia | proboscidea, K.-W. S | Van H | XXXI | 10 |
| 23 | 30 | Epithemia | turgida, Ehr | S. B. D. | I | 2 |
| 9 | 31 | Eunotia | arcus, Ehr | Van H | XXXIV | 2 |
| 9 | 32 | Eunotia | arcus var bidens, Gru | Van H | XXXIV | 7 |
| 15 | 33 | Eunotia | formica, Ehr. | Van H | XXXIV | 1 |
| 7 | 34 | Eunotia | incisa, Greg | Van H | XXXIV | 35 a |
| 38 | 35 | Eunotia | major, W. S.—Rab | S. B. D. | XXXIII | 286 a |
| 11 | 36 | Eunotia | pectinalis, K. | S. B. D. | XXXII | 280 a |
| 3 | 37 | Fragilaria | construens, Ehr | Van H | XLV | 26-27 |
| 8 | 38 | Fragilaria | virescens, Ralfs | Van H | XLIV | 1 |
| 5 | 39 | Gomphonema | abbreviatum, K. | Van H | XXV | 16 |
| 14 | 40 | Gomphonema | acuminatum, Ehr. var. coronata | Van H | XXIII | 15 |
| 20 | 41 | Gomphonema | brebissonii, K. | Van H | XXIII | 23 |
| 12 | 42 | Gomphonema | capitatum, Ehr. | Van H | XXIII | 7 |
| 11 | 43 | Gomphonema | commutatum, Gru | Van H | XXIV | 2 |
| 13 | 44 | Gomphonema | constrictum, Ehr. | S. B. D. | XXVIII | 236 a |
| 11 | 45 | Gomphonema | cristatum, Ralfs | S. B. D. | XXVIII | 239 a |
| 12 | 46 | Gomphonema | intricatum, K. | Van H | XXIV | 28 |
| 13 | 47 | Gomphonema | subtile, Ehr. forma Augusta | Van H | XXIII | 14 |
| 9 | 48 | Gomphonema | subtile, var. sagitta, Schuman | Van H | XXIII | 27 |
| 7 | 49 | Mastogloia | grivillei, W. S. | Van H | IV | 20 a |
| 9 | 50 | Mastogloia | smithii, Thwaites | Van H | IV | 13 |
| 3 | 51 | Melosira | crenulata, K. | Van H | LXXXVIII | 19 |
| 13 | 52 | Melosira | tympanum, Ehr. | ...... | ...... | .... |
| 13 | 53 | Navicula | acuta, W. S | S. B. D. | XVIII | 171 |
| 13 | 54 | Navicula | ambigua, Ehr | S. B. D. | XVI | 149 |
| 12 | 55 | Navicula | ambigua, forma craticularis | Van H | XII | 6 |
| 15 | 56 | Navicula | amphigomphus, Ehr | Van H | XIII | 2 |
| 13 | 57 | Navicula | amphirhynchus, Ehr | S. B. D. | XVI | 142 |
| 12 | 58 | Navicula | bacillum, Ehr | Van H | XIII | 9 |
| 7 | 59 | Navicula | borealis, Ehr.—K | Van H | VI | 3 |
| 12 | 60 | Navicula | braunii, Green | Van H | VI | 21 |
| 24 | 61 | Navicula | cuspidata, K. | S. B. D. | XVI | 131 |
| 32 | 62 | Navicula | cuspidata forma craticularis | S. B. D. | IX | 67 |
| 40 | 63 | Navicula | dactylus forma maxima, Ehr. | Van H | V | 1 |
| 13 | 64 | Navicula | dicephala, Ehr. (pinularia biceps, Greg | M. J., 1856. | I | 28 |
| 8 | 65 | Navicula | elginensis, Greg | M. J., 1856. | I | 33 |
| 20 | 66 | Navicula | firma (Iridis var.), Ehr.—K | Van H. | XIII | 1 |
| 6 | 67 | Navicula | frontinalis, Gru. | Van H. | XII | 33 b |

*Relative length or diameter 1=.0001 inch.

Abbreviations: Van H—Van Heurck's Atlas.
Schmt—A. Schmidt's Atlas.
S. B. D.—Smith's British Diatomaceæ.
M. J.—London Microscopical Journal.

| *Length. | Ref. No. | | | Author. | Plate. | Fig. |
|---|---|---|---|---|---|---|
| 18 | 68 | Navicula | gastrum, Ehr. (var. styriacea, Gru.) | †D. F. J. L. | A | 35 |
| 15 | 69 | Navicula | hemiptera, Ehr.—K | Schmt. | XLIII | 27 |
| 15 | 70 | Navicula | hitchcockii, Ehr. | Schmt. | XLIX | 35 |
| 13 | 71 | Navicula | interrupta, W. S. | S. B. D. | XIX | 284 |
| 9 | 72 | Navicula | laevissima, K. (Staawoneis rectangularis, Greg.) | M. J.. 1854. | IV | 17 |
| 14 | 73 | Navicula | lata, Breb. | Van H | VI | 1 |
| 23 | 74 | Navicula | legumen, Ehr | Van H.. | VI | 16 |
| 22 | 75 | Navicula | limosa, K. | Van H. | XII | 8 |
| 15 | 76 | Navicula | limosa, var. gibberula, K. | Van H. | XII | 19 |
| 12 | 77 | Navicula | limosa, var. ventricosa, Ehr.—Donk. | | XII | 24 |
| 30 | 78 | Navicula | ludloviana, A. S | Schmt | XLVI | 15 |
| 37 | 79 | Navicula | major. K. | Van H. | V | 3 |
| 12 | 80 | Navicula | mesolepta, Ehr | S. B. D | XIX | 182 |
| 12 | 81 | Navicula | mesolepta, var. stauroneiformis, Ehr. | Schmt | XLV | 53 |
| 50 | 82 | Navicula | nobilis, Ehr.—K. | Van H. | V | 2 |
| 8 | 83 | Navicula | slesvicensis, Gru | Van H. | VII | 29 |
| 11 | 84 | Navicula | trinodis, Lewis | ‡ | 2 | 6 a |
| 28 | 85 | Navicula | viridis. K | Van H. | V | 5 |
| 10 | 86 | Navicula | viridula, K | Van H. | VII | 25 |
| 21 | 87 | Navicula | vulpina. K. | Van H. | VII | 18 |
| 5 | 88 | Navicula | winchellina, N. Sp. (nav inflata., Donk.) | §D. B. D, | III | 9 |
| 32 | 89 | Nitzschia | amphioxys. K.—W. S | S. B. D. | XIII | 105 c |
| 11 | 90 | Nitzschia | thermalis, K. | Van H. | LIX | 22 |
| 31 | 91 | Stauroneis | acuta, W. S. | S. B. D. | XIX | 187 |
| 9 | 92 | Stauroneis | anceps, Ehr | S. B D | XIX | 190 |
| 23 | 93 | Stauroneis | gracilis, Ehr | S. B. D. | XIX | 186 |
| 61 | 94 | Stauroneis | phoenicenteron. Ehr | S. B. D. | XIX | 185 |
| 12 | 95 | Stauroneis | punctata, K.—Ehr | S. B. D. | XIX | 189 |
| 40 | 96 | Surirella | crenulata, Ehr. | | | |
| 56 | 97 | Surirella | splendida, Ehr. | S. B. D. | VIII | 62 |
| 80 | 98 | Synedra | capitata, Ehr | S. B. D. | XII | 93 |
| 100 | 99 | Synedra | longissima. W. S. ? | S. B. D. | XII | 95 |
| 12 | 100 | Tabellaria | fenestrata, K | S. B. D. | XLIII | 317 a |

*Relative length or diameter 1=.0001 inch.

Abbreviations: Van H—Van Heurck's Atlas.
Schmt—A. Schmidt's Atlas.
S. B. D.—Smith's British Diatomaceæ.
M. J.—London Microscopical Journal.
†—Diatomees de Frans Joseph Land.
‡—Notes on new and rare species, 1861.
§—London British Diatomaceæ.

## NOTES ON THE SPECIES.

No. 1. Achnanthidium flexellum Breb.=Cocconeis thwaitsii W. Smith. This diatom I found living at Copper Harbor, Lake Superior, and it occurs frequently in fresh water gatherings in the Eastern states. It is flexed in front view (f. v.), has dissimilar valves and a sigmord median line; outline of valve oval, aspect hyaline; not common in the deposit.

No. 2. Amphiprora ornata Bailey. First detected by him in the Croton water, and not uncommon in fresh water streams in the Eastern and Middle states. I have found it in filterings from lakes Erie and Michigan; one gathering from New Jersey has frustules nearly double the normal length. Bailey's figure, from Withlacooche river, Florida, is a rough outline; Mic obs. Smith Cont. 1850, Pl. 2, f. 15. In the list of Croton diatoms he considers it a Paludosa. I have never found it except contorted. The general aspect is hyaline,and the endochrome very delicately colored, and resembling in its arrangement that of a Nitzschia. Not common in the deposit and only broken frustules.

No. 3. Amphora ovalis K. Occurs abundantly in the living form and is cosmopolitan and not uncommon in sub-peat deposits. Ehrenberg describes and figures it as A. gigas in Abb. der Königl. Akad. 1870, from a deposit near Salt lake, Utah, where it is found associated with Surirella crenulata E, our No. 96. Not rare in the deposit.

No. 4. Campylodiscus clypeus E. I found only a few fragments of this diatom in the deposit. It occurs living at Petalume, Cal., and probably may be found in other western localities. I have not observed it in any gatherings from the great lakes.

No. 5. Cocconeis lineata E. Probably a variety of C. placentula, which is found in nearly all fresh water streams and ponds, densely incrusting stems of algæ, leaves of Potamogeton, etc. It is very variable in size; the larger forms are probably sporangial. The valves are generally broadly oval, and unlike: one, the lower, has median line and nodule. Common.

No. 6. Cyclotella kutzingiana. Exceedingly abundant in this deposit and of very variable size. C. meneghiniana is a more undulated form of this, and C. rectangulata is doubtfully distinct. The frustule is undulate in front view, and the valve, in s. v., shows this, especially the larger specimens, by a shaded band across a diameter, or a little one side of a diameter, and it is more or less apparent on all the valves. It is found everywhere living, and is common in almost all sub-peat deposits. Great confusion exists in the species of this genus.

No. 7. Cymatopleura hibernica W. S. This diatom is not very common, though I have found it living in gatherings from lake Erie, and also in fresh water deposits in the Eastern states. It is rare in the Minnesota deposit, and I found no whole frustules.

No. 8. Cymbella aequalis W. S. This pretty little diatom, which resembles a Navicula, is fairly abundant in the deposit. It has somewhat sharper ends than Greville's figure, Ann. & Mag. Nat. Hist. April 1885. Pl. ix, fig. 4. He describes it as having the striæ fine, but not close, and shows them in the figure rather too strongly marked. He found it in a peat deposit. It does not occur very frequently in the U. S., nor do I recollect ever meeting with it in gatherings from the great lakes. It occurs, however, fairly abundant near Richmond, Va.

No. 9. Cymbella affinis K. A small form, common, but not abundant in this deposit. The Cymbelleæ are generally present in all our sub-peat deposits, and occur extensively in the living condition in almost all fresh water gatherings. The distinction formerly made into Cocconema and Cymbella, based on the presence of a stalk or stipe for the former, is now properly abandoned; though Encyonema, generally found in the living condition in tubes, and which otherwise would fall into this genius, is yet retained. There is much confusion among these smaller forms of Cymbelleæ. Thus, I have specimens marked by Brebisson as C. affinis, which are C. ventricosa K.=Encyonema ventricosum, which is also C. ventricosa of Ag. Rut. Diat. Ex. No. 24, and given by Rabenhorst as a brackish species. C. affinis has a curved median line, extending to the extremities of the valve, while that of the Encyonemeæ is straight, or very nearly so.

No. 10. Cymbella cistula E.=Cocconema W. S. This diatom occurs plentifully in the deposit. It is distinguished from C. cymbiformis by being more bent or curved on the ventral margin of the valve, and also distinctly inflated. How far these can be accepted as specific characters is questionable. It is not difficult to find many intermediate specimens.

No 11. Cymbella cuspidata K. Common in this deposit, and varying considerably in size and distinctness of the produced ends. It is allied to No. 13, from which, however, it differs in its smaller size and finer striation. Both these forms are common in fossil deposits and in recent gatherings.

No. 12. Cymbella cymbiformis E. Common, and doubtfully distinct from No. 10, from which it differs only in wanting nearly or quite the inflation on the ventral margin of the valve, and in being much less curved. The striation is about the same.

No. 13. Cymbella ehrenbergii K. A large and fine species, distinguished from No. 11 by its much coarser striation and larger size, as well as sharper ends. It is not rare in this deposit.

No. 14. Cymbella gastroides K. This, and probably numerous other species, constituted by Grunow, Kutzing and Ehrenberg, on slight differences of form or size, is probably but a variety of No. 15. It is not common in this deposit and is distinguished mainly by its blunt ends. C. stomatophora Grun., which is a variety of this diatom, occurs living in the great lakes, and numerous varieties of this and the other Cymbellæ occur in nearly all our sub-peat deposits.

No. 15. Cymbella lanceolata=Cocconema W. S. This form, well figured in S. B. D. Pl. 23, fig. 219, is the same as the typical slide of C. gastroides, Eulensteins series No. 93. It is the largest of the Cymbelleæ found in this gathering, and is pretty abundant, though the frustules are mostly broken. It differs in size and coarser (moniliform) striation, from Nos. 10, 12 and 14, and may be a sporangial form.

No. 16. C., parva I have found conjugating, and the sporangial frustules were C. cymbiformis, and as in the case of Nav. amphigomphus, I have actually found the sporangial forms, (and in the same gathering) conjugating and producing the largest frustules, N. iridis. It is quite possible that these larger forms now designated C. lanceolata, and C. gastroides, may be sporangial forms of C. cymbiformis or C. cistula, and that Nos. 10, 12, 13, 14, 15 and 16 are but one species. C. parva is common in this deposit.

No. 17. Cymbella subaequalis Grun. Not common in the deposit, nor have I observed it in any other of the sub-peat deposits, or recent gatherings. Its occurrence therefore though rare in this particular deposit,is interesting. The figure given by Van Heurcks,atlas Pl. III fig.2 is a good representation from specimens found at Brussels. The valve is naviculoid with blunt ends, and distinctly striated.

No. 18. Denticula elegans K.=D. ocellata W. S.; rather rare in this deposit. It is distinguished by the rounded ends of the valves; and the strong pervious transverse costae or ribs, give it the ocellated appearance, which distinguishes it from other species. This form, and the next, with many of the Epithemiae, abounds in the thermal waters of the National Park.

No. 19. Denticula tenuis K. More abundant than the preceding, but not common. It is frequently found in ordinary fresh water gatherings; striation quite conspicuous.

No. 20. Encyonema cæspitosum K. A marked character of this genus, which after all, is but Cymbella living in tubes, while the Cocconemeae slip out and the contracted tube forms a stipe, is this, viz, the median line in the other forms, terminates in the ends of the valves, while in Encyonema, it is nearly straight and terminates within the convex margin of the valves. This is a very conspicuous feature in the larger form, but may be noted also even in the smaller forms like the present one, which is tolerably abundant in the deposit. It is a common recent form.

No. 21. Encyonema gracile E. This is probably the Cymbella scotica W. S. It is a slender and somewhat longer form than the preceding, and more delicately striate and with sharper ends; it is pretty abundant in the deposit.

No. 22. Encyonema prostratum Berk. This is the largest and most robust form, coarsely moniliform striate, and exhibiting in a marked manner the peculiar features of the median line already alluded to. It is not abundant in this deposit, nor indeed in any of our sub-peat deposits. It is not uncommon in recent gatherings.

No. 23. Encyonema turgidum Gregory. This diatom is common in the deposit; it has sharp ends, and is coarsely moniliform striate.

No. 24. Encyonema ventricosum K. Smaller than the preceding; the ends are slightly produced; it is C. affinis of Bret., and C. ventricosa Ag. It is very variable in size; some frustules are smaller than those of No 20, but unlike these latter, they are almost straight on the vertical margin—abundant.

No. 25. Epithemia alpestris, W. S. This is, no doubt, a variety of No. 28, and also E. argus, as already suggested by Dr. Walker-Arnott, Microscopical Journal, Vol. VII, 1859, fig. 174. They are all distinguished in front view by a series of inter-margined ocelli, or foramina, as they are termed by W. S.,though they are not openings at all,but siliceous nodules, and from these "eyes"comes the specific name argus. E. alpestris was separated as having produced somewhat recurved extremities, and nearly straight sides in f. v. Not rare in this deposit.

No. 26. Epithemia gibba K. This diatom is not as abundant as the preceding, and the valves are mostly broken. It is quite distinct from the other Epithemiae, for while these latter are adherent by the concave margin of the frustule, to the stems of confervæ, in the living condition; Epithemia gibba adheres by one end. It is further distinguished by the absence of granules on the valves, as in the other species.

No. 27. Epithemia granulata K. This form is perhaps the most abundant of the Epithemiae in the deposit.and is characterized by its long arched valves and slightly produced ends; and it appears to be somewhat more finely striated and granulated than No. 30, of which, however, it may be a variety.

No. 28. Epithemia ocellata K. The inflated frustules and blunt, not produced ends, served to separate this from No. 25. As already remarked these are features of doubtful specific value. This diatom is much less common in the deposit than No. 25.

No. 29? Epithemia proboscidea K. There appears to be some doubt about the E. proboscidea of W. S. being this form, as the latter is more coarsely marked and the valves are much more arched, and the ends more produced and recurved. The examination of W. Smith's original specimens shows that it is quite distinct from our present form.

No. 30. Epithemia turgida. This is doubtfully distinct from No. 27. Valves somewhat more arched, and apparently, not really, more coarsely granulated, and the ends are somewhat more recurved. It is not as common in the deposit as No. 27.

No. 31. Eunotia arcus E. This is not the Eunotia arcus W. S. which is a very different diatom,but it is Himandidium arcus W. S., a name given to the species of the genus which cohered after self division, forming a a ribbon or filament of frustules, a character considered now of no specific value. E. arcus is very variable in size and outline, it is generally arched, somewhat more convex on the dorsal margin, and has produced ends; the ventral margin is nearly straight and the valve is transversely and conspicuously striated. It is very abundant in the deposit and occurs plentifully in the many sub-peat deposits.

No. 32. Eunotia arcus var. bidens Grun. This variety is common, and is also, like E. arcus, variable in size.

33. Eunotia formica E. differs from No. 31 in having the ventral or concave margin of the valve, sharply undulated at the middle. It is the Himandidium undulatum of W. S. and is not uncommon in the deposit. It is very variable in size.

No. 34. Eunotia incisa Greg. This is a small form, more delicately striated than the preceding, and is rather abundant in the deposit. It occurrs in gatherings and fossil deposits of high latitudes in great abundance. The valves have a decided little notch near the ends, on the concave or nearly straight margin. This notch is, in the other Eunotiæ, replaced by an inter-marginal nodule.

No. 35. Eunotia major W. S.—Himantidium W. S. It is doubtful whether this is anything more than a large variety of E. arcus. It is abundant in the deposit.

No. 36. Eunotia pectinalis K. This diatom is but a variety of E. arcus. It was called Himandidium pectinale by W. S., and the frustules do adhere very firmly; but it differs in no way from E. arcus except to have the dorsal margin of valve flat, or even slightly indented, and it is generally somewhat smaller. Common.

No. 37. Fragilaria construens—staurosira E.—Odontidium tabellaria W. S. Valves small, hyalin, and inflated, sometimes so small as to resemble a small cross, and not unlike small specimens of Tabellaria flocculosa with which it has been confounded; it occurs in filaments of 5 to 10 frustules in the prepared slides, and is not rare. An abnormal form of this, and found only in a single gathering at Ormsby, Eng., wanting one of the arms of the cross, was called by W. Smith Triceratium exiguum; along with it in the same gathering was an abundance of the normal form with both the inflated and the stauriniform valves. It is not rare in both forms in the Minnesota deposit. The inflated valves are Kutzing's Navicula inflata, K. B. Tab. 3 fig. 36. Odontidium parasiticum W. S.=Fragilaria binodis E. is probably this diatom.

No. 38. Fragilaria virescens. Not rare to the deposit, both the valves with constricted ends and filaments of a few frustules.

No. 39. Gomphonema abbreviatum E. This small form is not uncommon in the deposit, the striæ are marginal, and easily seen; it may be a very small form of No. 43. It is difficult to decide whether this is Kutzing's species.

No. 40. Gomphonema acuminatum E. The Gomphonemæ are quite abundant in this deposit; and intermediate forms, between species constituted by Ehrengberg and many of the continental observers, are not rare. The present form, however, is well marked, quite variable in size, and readily recognized. Nos. 47 and 48 are probably slender varieties of the present diatom.

No. 41. Gopmhonema brebisonii K. This, which is a large, well marked variety of the preceding, and is probably same as G. turris E., occurs in considerable abundance in this deposit., It is a marked variety, and possibly a distinct species. It occurs living in the great lakes and their tributaries, as also all the other forms in this list.

No. 42. Gomphonema capitatum E.—G. elevatum E. This diatom is very abundant in the deposit, and also living in the great lakes. A large variety has been called G. herculeanum by Ehrenberg, and G. oregonicum E. and G. giganteum E. are probably varieties, as also Grunow's G. robustum. It is very variable in size in the deposit.

No. 43. Gomphonema commutatum Grun., occurs abundantly in the deposit. I have not observed it living. It is more conspicuously striated than the smaller forms of the preceding; striæ marginal; it is allied to G. vibrio, and except in the somewhat greater breadth of the valve is not to be distinguished from No. 46.

No. 44. Gomphonema constrictum E. The passage from No. 42 into this form is very easy, the capitate head is more constricted and rounded, and intermediate forms are not rare. It occurs in the deposit about as frequently as G. capitatum and is a common form, living in nearly all fresh waters.

No. 45. Gomphonema cristatum Ralfs. This is an intermediate form between the last and No. 40. Not as frequent in the deposit as the latter and generally smaller.

No. 46. Gomphonema intricatum K. Grunow's G. commutatum is allied to this, and G. hebridense of Gregory is probably the same. The striæ are marginal and the central nodule is almost midway from the ends of the valve, in this respect differing from the normal G. commutatum; but intermediate forms are abundant in the deposit.

No. 47. Gomphonema subtile. This is a very slender form of G. constrictum, and so also is No. 48, and both should be considered as varieties.

No. 49. Mastogloia grevillei W. S. This diatom is somewhat rare in the deposit and, so far as I am aware, has not been found in any other of our fossil deposits, or indeed in any gatherings from the western lakes. It is a small, coarsely-marked form, valves with cuneate ends, and the peculiar inflation figured in the British Diatomaceæ, Supp. pl. LXII, fig. 389*a*, on the under surface of the valves near the ends, is quite apparent. The frustules found in the deposit are all smaller than the original, found at Portland hills by Dr. Greville, but otherwise agreeing completely.

No. 50. Mastogloia smithii W. S. This diatom is rarer than the last in the Minnesota deposit. It is, however, a much more common form in fresh water gatherings. As found in the deposit the valves are somewhat narrower and with sharper ends than the normal form. The loculi are conspicuous and the striation much finer than that of M. grevillei.

No. 51. Melosira crenulata K. The absence of Melosireae from the Minnesota deposit is a marked feature, inasmuch as they constitute the larger portion of many of the Oregon, California and other fossil deposits of the Pacific coast, and they occur abundantly, living in all our fresh waters; but few frustules were found of this diatom. It is probably but a variety of M. nichalcea (orthosira) W. S.

No. 52. Melosira tympanum E.? It is somewhat doubtful whether this is the form described by Ehrenberg as occurring in the fossil deposit, Truckee river, California, but the few valves which I have found agree well with his figures.

No. 53. Navicula acuta W. S. Not very abundant in this deposit though not rare.

No. 54. Navicula ambigua E., rather rare in the deposit; the craticulate form is somewhat more abundant; perhaps this may be owing to the striking character of the latter, which makes it so much more conspicuous. These craticulate forms, arise from the persistence of the sporangial sheath which envelops the frustule. The striation on the valves, can be detected in under this. The ribs on the sheath, are much more pronounced in this form, and in No. 61 to which it is closely allied, than in any other of the Naviculeæ. N. brebissonii perhaps comes nearest, and a new genus Perizonium, was constituted to receive the craticulate variety of this diatom, which was called P. braunii. I have observed these rib-like markings in the sporangial sheaths of N. viridis, but none are so conspicuous as these of N. antiqua and N. cuspidata. The genus Stictodesmis of Greville, appears to be founded upon this character, and I have observed it in a small marine form, no ways differing from antiqua. The resemblance of these craticulate markings to those of Surirella, induced W. Smith, in the Birtish Diatomeceae, to figure and describe our No. 62, as Surirella craticularis.

No. 56. N. amphigomphus E. This is a variety of N. iridis E. with wedge shaped ends. The typical N. iridis is precisely like N. firma, No. 66, but larger. It is not rare in the deposit, and, like all the varieties of N. iridis is finely striate, and shows apparently a few intra-marginal lines parallel with the sides of the valve. All the varieties are common in our sub-peat deposits.

No. 57. Navicula amphirhynchus E. This variety of N. iridis, which scarcely differs from N. producta, is characterised by the produced ends. It is not rare in the deposit. The ends of the valve are blunt and there is a blank space around the central nodule.

No. 58. Navicula bacillum E. This small and somewhat hyaline diatom is not rare in the deposit. The valve has round ends and straight sides, and a distinct median line, with a blank space around the central nodule; striation fine. It occurs in many of the eastern sub-peat deposits. I have not observed it living in any gatherings from the great lakes, but it is abundant in some of the fresh water ponds of the New England states, and in fossil deposits from Sweden and Norway. N. bacillaris, Grey is smaller and more finely marked, and is without the central blank space.

No. 59. Navicula borealis E. K. This small and coarsely marked diatom. N. latestriata of Greg., is usually found among damp mosses on trees; it is not rare in the Minnesota deposit.

No. 60. Navicula braunii Grev. A small form, allied to N. gibba, and tolerably abundant in the deposit; the valve is inflated and has constricted and rounded ends; striæ marginal.

No. 61. Navicula cuspidata K. This fine diatom, which occurs plentifully in recent gatherings and in many sub-peat deposits; is not very common in the Minnesota deposit. The craticutale form appears to be somewhat more plentiful, and is a very striking object, and generally a little larger than the diatom as usually met with. As already remarked under No. 54 this form, our No. 62, was called Surirella craticula by W. Smith. The valves are finely but distinctly striate.

No. 63. Navicula dactylus E. Distinguished from N. iridis by its size and coarser pinnæ, and from N. major and N. nobilis by its straight, not inflated sides. Whether these features warrant a new species is questionable. The distinction into Pinnulariæ and Naviculæ, the former having smooth (apparently) ribs, or pinnae, and the latter striæ made up of fine dots (moniliform), is now abandoned, and all are termed Naviculæ. The species mentioned above are very common in sub-peat deposits and in recent gatherings. The marine forms with smooth ribs are comparatively few.

No 64. Navicula dicephala E. This is the Pinnularia biceps of Gregory, who supposed it new, but this name "biceps" had already been given by Kutzing to a different diatom, and as Ehrenberg has, no doubt, given the name "dicephala" to several entirely different forms, one of which is the "dicephala" of W. Smith and our No. 65, perhaps it would be better to adopt Lagerstedt's name and call the present form N. bicapitata. It is a well marked, though not large form, with straight sides and constricted rounded ends, (not unlike a "rolling pin"), it is dictinctly striate, and is fairly abundant in the deposit.

No. 65. Navicula elginensis Greg. This is the N. dicephala of W. Smith; it is smaller than the preceding, and the valve not unlike it in outline; the sides are generally a little incurved, and there is a peculiarity in the appearance of the central nodule, which at once distinguishes it from No. 64, which has a blank space around the nodule, absent in this form. This striation is rather coarse. It is about as abundant in the deposit as No. 64.

No. 66. Navicula firma. This is a smaller form of N. iridis, and not rare in the deposit.

No. 67. Navicula fontinalis Grun. I am not quite certain that this small diatom, which is very rare in the deposit, is Grunow's species. About a third of the length of the valve, the middle portion is blank, giving the impression of a wide stauros.

No. 68. Navicula gastrum E. var. styriaca Grun. This fine diatom, which is not uncommon in the deposit, reminds one at first glance of Stauroneis punctata. It is, however, larger and much more coarsely marked. The ends are produced in this variety, rather more than in the normal N. gastrum, only one specimen of which I observed in the prepared slides. The striæ are absent from the center, much as in Stauroneis punctata. It is a characteristic form in the deposit, and I do not recollect observing it in any other of the sub-peat deposits, or even in any recent gatherings. The normal form of N. gastrum, as figured by Donkin, has been found by Thomas and Chase in the water supply of the city of Chicago, from lake Michigan.

No. 69. Navicula hemiptera E. Not rare in the deposit; it is a small form, striæ marginal, outline of valve like N. iridis, but somewhat narrow in proportion to length.

No. 70. Navicula hitchcockii E. Quite abundant, and rather larger than those which I have found in the eastern sub-peat deposits, or in recent gatherings. It has a hyaline aspect and is allied to the variety of N. limosa, called "gibberula" by Kutzing. The ends, however, and central inflation, sharper; but it must be confessed, that some small forms of N. gibberula, approximate very closely to it.

No. 71. Navicula interrupta W. S. This is not the N. interrupta of Kutzing, which is only a variety of N. didyma E.; we may, therefore, retain W. Smith's name. Really, this species is a staurineiform variety of our No. 64, and exactly like it in every respect, except the central blank space or stauros which characterizes the present form. It is not so abundant in the deposits as No. 64. Nos. 80 and 81 are similar examples.

No. 72. Navicula laevissima K. Stauroneis rectangularis Gregory. A smaller form than N. bacillum, to which it has a remote resemblance, but the margins of the valves are slightly undulate and the striation somewhat coarser, and instead of the circular central blank space there is an arrangement of the central striae giving the impression of a sort of stauros. It is fairly abundant in the deposit.

No. 73. Navicula lata Breb. This diatom is somewhat rare in the deposit, and at once recognized by the very coarse and distant pinnae: N. borealis is probably a very small variety. I have not observed it in any recent gatherings, but it is found in some of the fossil sub-peat deposits of New England.

No. 74. Navicula legumen E. This fine diatom is also rare in the deposit. The valve has three distinct undulations and rounded ends; the striae are radiate, not reaching the median line, and there is a large central blank space, or pseudo-stauros around the central nodule.

No. 75. Navicula [illegible] K. This and its varieties are common in the deposit. It belongs to the N. iridis group, and is distinguished by the inflation at the middle of the valve.

No. 76. Is a variety of the preceding, with smaller and sharper ends and somewhat deeper constrictions.

No. 77. Navicula ventricosa E.—Donk. Smaller than N. limosa, and less inflated, the sides of the valves are nearly straight; it is characterized by having a transverse blank space around the central nodule, and is not as common as Nos. 75 and 76.

No. 78. Navicula ludloviana A. S. This fine diatom has a resemblance to N. peregrina, which, however, is a marine species; it is characteristic of the Minnesota deposit. It is about the size of N. peregrina, but has a larger blank space at the central nodule. It is found in fossil deposits at Shasta, California, and is figured in Schmidt's Atlas; striae radiate conspicuous and not reaching the medium line.

No. 79. Navicula major K. A large form pretty abundant in the deposit, and differing from N. iridis and N. dactylus by having the valve inflated at the middle.

No. 80. Navicula mesolepta E. This is fairly abundant in the deposit. It has three central inflations and is deeply constricted towards the obtuse extremities. It is N. nodosa, E., a form confounded sometimes with N. legumen, and the latter may possibly be a sporangial form of this diatom.

No. 81. Navicula mesolepta var stauriniformis E. Exactly like No. 80, with the exception that this variety has a distinct central blank (stauros). It is not quite as common in the deposit as No. 80.

No. 82. Navicula nobilis E. K. This is a very large form of N. major, and not rare in the deposit, though the frustules are generally broken.

No. 83. Navicula sleavicencis Grun. This diatom is probably a variety of N. viridula, and is pretty abundant in the deposit. The striation in our form is somewhat more radiate than in Grunow's species, and the ends are a little more produced; but in the main it agrees so closely with specimens from Grunow, that I have little hesitation in adopting his name. The valves are slightly inflated and striae distinct.

No. 84. Navicula trinodis Lewis. This is not the N. trinodis of W. Smith, which is very much smaller and has rounded ends, and was considered by Dr. Arnott as Achnanthidium. The present form was first figured by Lewis, in Notes on New and Rare Species of the United States Seaboard. Phil. 1861, Pl. II fig. 6. His figure shows the striæ too plainly, for it has a hyaline aspect, and is not very rare in many recent gatherings. The constrictions are very much deeper, and the ends sharper than in N. gibberula; it is more like N. hitchcockii, but smaller, and more deeply constricted. It is rare in this deposit, but is found in some of the eastern sub-peat deposits.

No. 85. Navicula viridis K. Abundant, and variable in length and breadth; ends of valve round, and sides scarcely inflated; striæ or pinnæ conspicuous.

No. 86. Navicula viridula K. Common in the deposit, and variable in size; valves inflated and with punctured ends. It is one of the commonest of our fresh water forms.

No. 87. Navicula vulpina K. This diatom, which is not rare in the deposit, resembles N. ludloviana, but is somewhat more finely striate and with sharper ends, and wants the central blank space.

No. 88. Navicula winchelliana, n. sp., H. L. S. This small, but well marked diatom, is not very rare in the Minnesota deposit. It has been figured by Donkin Brit. Diat., pl. III, fig. 9, as N. inflata of Kutzing. An examination of Kutzing's figure, on the Santa Fiore deposit in which he found it, would have shown that Kutzing's diatom was Staurosira construens. The N. inflata of W. Smith is still another form found in the Peterhead deposit, and quite distinct from the present one which Donkin quotes as found in the Lough Mourne deposit. The latter agrees in all respects with our form, and is well figured by Donkin. It is characterised by having the two or three central striæ somewhat stronger or farther apart so as to give the appearance of a pseudo-stauros. No. 253 Cleve and Moller, Nav. viridula, var. ampiceros as figured in Schmidt's Atlas, might probably be mistaken for this, but wants the peculiar pesudo-stauros and is much larger and quite distinct. As the specific name inflata must be retained for W. Smith's form, I name the present one after Prof. Winchell, who discovered the deposit.

No. 89. Nitzschia amphioxys K. W. S. Not rare in the deposit, but very variable in size. The larger ones are generally broken.

No. 90. Nitzschia thermalis. Less abundant than N. amphioxys, and distinguished by the valve having straight or slightly incurved sides and sharply constricted capitate ends. The paucity of Nitzschiæ in this deposit is marked.

No. 91. Stauroneis acuta W. S. Not uncommon in the deposit. The valve has straight or somewhat incurved sides with sharp ends, and presents a rhomboidal aspect; striae distinct. It is found in recent gatherings with the valves adhering somewhat tenaciously into a filament of six or nine frustules, and is not uncommon in sub-peat deposits.

No. 92. Stauroneis anceps E. This is a small form with produced capitate ends, and finely striate, and is sparingly abundant in the deposit. There are intermediate forms between this and the next No , so that it is doubtful whither this is not a variety. The stauros barely extends to the margin of the valve.

No. 93. Stauroneis gracilis E. Much like the preceding but more distinctly striate and longer, ends of valves slightly produced; not capitate. This is really the parent frustule of S. phoenicenteron.

No. 96. Surirella crenulata E. Only a few fragments of this were found. It is quite common in the fossil deposits from Utah, and is figured by Ehrenberg, Abh. der Könighl Akad, 1870, T. II, and fig. 6.

No. 97. Surirella splendida E. Fragments only were found of this diatom, but more abundant than the last. It is a very common form in recent gatherings and in sub-peat deposits. No other species of the genus Surirella were observed in the deposit.

No. 98. Synedra capitata E. Broken frustules of this were not rare, and also of the next species.

No. 99. Synedra longissima and possibly of S. radians. They were too fragmentary to decide.

No. 100. Tabellaria fenestrata K. Abundant.

# *THE PREPARATION OF DIATOMACEÆ.

BY DR. CHRISTOPHER JOHNSTON.

In all the range of microscopic research there is confessedly nothing which offers more seductive attraction than that department of botany which comprises the *Diatomaceæ.* Apart from the exclusiveness with which the microscopist makes his observations and pushes his inquiries, there are charms which attach to the life, the modes and the extent of the reproduction, and to the vast results which follow the multiplication of these organisms. There is also a pleasing bewilderment in their large variety of form and dimension, from the grosser discoids to the almost infinitely little living chambers; and a perpetual delight afforded by their architectural beauty, and by the marvelous and matchless delicacy of the designs sculptured upon the siliceous skeletons of their frustules. The man of science pauses in his work to pore over the tracery of detail, and the philosophic student exhausts resource to effect combinations in objectives and in oculars which shall serve to bring the "markings" into view and to perpetuate the picture by photography.

However great the interest which life, habits, and reproduction inspire, the structure and configuration of the siliceous part especially command attention; for this flinty framework, resisting time and decay, alone endures, and is a recognizable integral in vast strata of the earth's surface, while the softer organic portion, leaving the character of the diatom to the skeleton, is caught up and utilized in obedience to the law which compels organic matter to incessant action, whether it mount successively higher or fall within the scope of the humblest organism. This animated matter loses its identity, and its relations to particular forms, but the silicified cachet of *Triceratium* and of *Coscinodiscus* is as palpable in the pillared rock or the California stratum as in the recent condition, or in the softer "deposits" of Nottingham, Md., and of Moron, Spain, or in the guano accumulations of the Chincha and other islands.

"Preparation of the "Diatomaceæ" ought strictly to signify the preservation of individuals or groups of these organisms in a permanent way, and their arrangement in a condition suitable for study and future reference. We would begin with the deep seasoundings and end with animated pool water. It is not our purpose, however, to discuss at present the various devices adapted to accomplish a task so extended; but we desire to point out those methods of isolating the siliceous parts of Diatoms to which experience has given reputation.

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*The Lens, vol. 1, page 197.

It may be worth while to premise by stating—what is, of course, familiar to the student—that the coveted forms are to be met with in a great variety of conditions, either swarming fresh and full of life in pools, ponds or estuaries, clothed in fibres of green, brown or yellow, or clustering together in springs, pullulating in lakes and rivers, or tossed by the waves of the great ocean itself. In some of these situations the Diatomaceæ become and are the pabulum of myriads of beings, in whose bodies, as the *Acalephs*, the *Salpidæ*, the *Molluscs* and the *Holothuridæ*, their siliceous remains are constantly found by the microscopists, who use these and other creatures for their dredgers. They live with and upon other *Algæ*, and are met with in the green ooze of *Confervoids*, and even among the *Muscidæ*.

As ancient or recently fossilized, however, forming strata of considerable thickness, of widely different consistency and density, and not unfrequently of wide-spread geographical distribution, the Diatomaceæ astonish even the workers in science by the extent of their proliferation, and by the uneventful quiet of their living and dying, apparently undisturbed for whole ages in the conditions of their existence. Examples of these tedious and slowly cumulative formations may be instanced in Cassel, in California, in Jutland and in Maryland and Virginia, the latter furnishing so many varieties of configuration and such rare beauty in design and ornamentation. One of these diatoms, the *Heliopelta*, so much admired, has been selected by a distinguished author to grace the front page of his admirable work on the microscope.

It must be apparent that no one procrustean method of securing the prize can be made applicable in the business of "preparation." The extreme delicacy of *Amphipleura* forbids the rough boiling which *Coscinodiscus* invites; the free recent forms of any kind in "pure gatherings" obviously require nothing more than the destruction of the organic part, else the fairy-like embossing, as shown in lines or dots, is blurred, or disappears; while the so-called Diatomaceous "earths" or clays often tenaciously resist the deliverance of the imbedded gems, made adherent by a filmy, glassy cement, the product of time, an alkali, and a portion of the seeming lithophytes of other epochs. A lacustrine deposit may be washed out clean with water, but rock must be softened and sulphate of lime removed by boiling chlorhydric acid.

In general, the business of preparation involves two distinct processes: *first*, the liberation of the diatoms (as we shall henceforth, for convenience, call the siliceous skeletons of the *Diatomaceæ*) from all extraneous matters, with the exception of amorphous silex or some silicates; and, *secondly*, the complete isolation of the diatoms themselves. The former is, at times, toilsome and disagreeable, by reason of acid fumes which arise in its course; the latter is tedious and, like the other, time-consuming. But both call for a clear knowledge of method and precise executive manipulation, and both demand of the operator an intelligent adaptation of means to an end, and the *patience* with which the attainment of the end is made possible.

The simplest methods of cleaning are not always the most easy,—for example, the rescuing of diatoms from among the *Polycystinæ* of Barbadoes,—nor the most complicated always the most difficult, as, for instance, the treatment required by a sulphate of lime guano known here as the "Algoa Bay." Let us, however, attempt to make the several methods distinctly comprehensible, although in so doing we run the risk of emulating the tediousness of "neighbor Verges."

*Apparatus and Chemical Material.*—Guided by our experience, the following-named articles are recommended as necessary for the work of cleaning and isolating Diatoms, which should be done in a chamber high above the ground, if possible, and not heated in winter by a flue. Hot-water pipes are far better, as affording immunity against dust. We enumerate:

German beaker glasses of different sizes, with a number of small china plates to serve as covers, several large watch-glasses, or shallow glass capsules of like shape; solid glass rods for stirring; small glass tubes or pipettes; a sand bath and an apparatus for heating; nitric acid, chlorhydric acid, sulphuric acid,—all the best "commercial," except the last, which should be "C. P."; carbonate of soda and carbonate of potassa, both C. P.; Atkinson's alcohol, freshly distilled water, and a copious supply of filtered soft water.

For displaying a cleaned sediment with the view of securing individual specimens, a number of glass slides one and a half inches by four inches should be provided; and for the preservation of finished work or clean diatoms, a score of small bottles, with corks already fitted.

Finally a large camel's-hair pencil; a few slender cane (reed) strips, to serve eventually, when pointed very finely, to pick out single valves; a supply of litmus paper; a glass funnel, and Saxony filter paper, complete the category.

*Method to be Employed.*—As pure diatoms, guano findings, and diatomaceous earths or clays each require separate modes of treatment, let us first handle a guano specimen, because some of the steps to be trodden may be called fundamental, or we may say they are of very general application; still, they must in certain instances be preluded by others, may not be wholly needed in particular cases, and are of necessity to be followed by supplementary processes demanded by the peculiar nature of the products obtained.

A guano, such as the Chincha or that of Ichaboë, ought to be coarsely sifted to free it from pebbles, feathers, and masses of crystallized substances. The better part is still, however, very heterogeneous, consisting of diatoms in very small percentage, and of much extraneous matter, earthy, salty, and excrementitial. Boiling water dissolves a great part of all these, and should be repeatedly applied to the deposit, and as often suffered to stand after stirring, so as to leave behind the insoluble constituents, among which, of course, are the objects of our search.

The sediment will be materially lessened in bulk by a good boiling in a solution of carbonate of soda, one ounce to the pint, which dissolves much organic as well as some inorganic matter, and, besides, sets free adherent diatoms without injuring their structure. Carbonate of potash, however, is not so free from objection.

The residuum, being drained upon a filter, ought now to be boiled in an equal part dilution of nitric acid for about ten minutes in a beaker glass, the quantity of the fluid being a couple of inches in hight above a half-inch of the matter upon which it is destined to act. Lime not in the form of sulphate, and some other elements, are dissolved out as nitrates, and must be poured off in the solution when cold after standing. Hot water should now be added freely to the sediment and poured off after its subsidence until all acid shall have been removed, whereupon the residuum is to be once more drained upon a filter.

The matter remaining is now ready for pure nitric acid, in which it is to be boiled for five or even ten minutes; after which treatment, and before cooling, the whole must be deluged with hot water. After standing, the supernatant liquor is to be poured off, and the refractory deposit washed clean with cold filtered water, and drained as before stated.

The sediment now much reduced in quantity, is prepared for chlorhydric acid, in which it is to be boiled for the removal of sulphate of lime if in moderate quantity, perhaps of a small percentage of other matter, and of such metallic stains as have resisted the action of the aquafortis. Besides, the chlorine has bleached such vegetable organic debris as has escaped destruction, so that the sediment, now composed of diatoms, fine sand and siliceous dust, and extraneous vegetable remains, appears of a pale gray color.

When thoroughly washed in filtered or distilled water, and then rendered as free from moisture as possible, either by means of a filter or by gravitation, the deposit must be subjected to the action of sulphuric acid, C. P., which heated to the boiling point carbonizes the vegetable matters, which, in a charred state, blacken the fluids. The removal of this carbon is to be accomplished in the form of carbonic acid by the addition to the still boiling acid of oxygen, which at the very high boiling point of sulphuric acid combines with it, and the gas escapes in ebullition. Nitric acid ($NO_5$), may be slowly dropped in, one drop a time, (being very careful to protect the eyes, face and clothing from the miniature pyrotechnics that may result), until the black or dusky color gives place to the orange hue of nitrous acid ($NO_3$), being what is left of the nitric acid that has parted with two elements of oxygen; or else chlorate of potassa in fine powder, after the manner of Bailey, may be very gradually, and in small doses, dropped into the seething liquid. Upon each contact of the powder a vivid explosion takes place as the carbonaceous particles ignite and consume. Chlorine is evolved, to the great annoyance of the operator, and sulphate of potassa is added measurably to the sand and diatoms beneath. But soon all is of pearly whiteness, and the process is at an end.

The task of cleaning is near its accomplishment; for all that remains to be done is the abstraction of the acid and the washing out of the sulphate of potash.

Let the tyro be careful, and manipulate with deliberation; for the rapid admixture of sulphuric acid and water occasions a sudden and considerable rise of temperature. Instead of pouring or drawing off the hot or cooled fluid, we would recommend that a large beaker glass two-thirds full of hot filtered or distilled water be made ready, and that into the water, by very tardy pouring, or even dropping, the acid, and all it contains, be thrown. When cold, or nearly so, the supernatant fluid must be flowed away, which process is facilitated by holding a glass rod against the beaker's edge to guide the stream, and after repeated washings with distilled water in a fresh beaker (for the sulphuric acid clings to the pot-beaker), the diatoms, the sand, and the amorphous silica alone survive. All is now perfectly clean; but the constituents of the white powder must await separation, and this they can do only in *dilute alcohol*, because the particles mat or adhere irretrievably in water, in which, also, confervoids speedily arise. We *label* the vessel, and we choose our own time for isolating the precious forms, observing, however, that the whole sediment has shrunk within very small dimensions, as we set aside the result of so much labor.

Finally, in reviewing the work done, let us have in mind the intention of each of the acids employed, and remember that $NO_5$ boils at a moderately high temperature, which, as in other fluids, is increased by the presence of pebbles, bits of glass, or coarse sand; that $HC_1$ passes into ebullition at a comparatively low indication of the thermometer; and lastly, that the boiling point of $SO_1$ is very high indeed,—so elevated, in fact, as to jeopardize all inferior glass-ware.

The foregoing process is open to the charge of being time-consuming,—as are all other methods,—but we have invariably found the results to be excellent. The same success is claimed for a different procedure, practiced and recommended by F. G. Stokes,* and which may be here briefly set forth.

"Provide a beaker glass of six or eight ounces capacity, in which place about two teaspoonfuls of guano, and then fill to near the top with a saturated solution of carbonate of soda. Boil for half an hour, wash well with water, and, after standing, pour off the supernatant fluid very close.

Add now of chlorhydric acid two ounces, boil also for a half hour, wash well, and pour off very close once more.

Treat the sediment with one ounce of strong sulphuric acid. Let it act for ten minutes, and then add bicarbonate of soda cautiously, either in solution or suspension. Shake well during effervescence, wash well, and, with great caution, add two ounces of nitric acid. After effervescence, drop in two pinches of chlorate of potash, boil a half hour, or until the deposit becomes white, and, finally, wash the sediment thoroughly."

From what precedes, it must appear that the aim of the operator is the removal of all inorganic substances, either originally soluble or artificially made so, prominent among which is *lime*, and of all organic matters reduced by a destructive process to a soluble or gaseous form. And it is also evident that when certain of these strange elements are known to be absent, such parts of the processes as are applicable to them ought to be omitted, so that fewer steps are necessary to attain the end. Silex, or sand, of course, is not to be regarded in this connection, as it is as insoluble as the Diatoms themselves.

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* F. G. Stokes, On Cleaning Diatoms, Quar. Jour. Micros. Science, vol. xv. p. 222.

Suppose we take a clay or earth, that of *Nottingham*, for example. Cretaceous matter forms but a small part of its substance, which consists, in fact, of Diatomaceous skeletons, more or less adherent through the agency of a mortar, probably a silicate of lime, and of fine siliceous particles, or even sand, less closely connected. To disintegrate a mass, let it first be slaked, as it were, by pouring over it a strong solution of carbonate of soda, and when, after a time, the whole falls to pieces in laminæ and in dust, let it be boiled for fifteen or twenty minutes in a quantity of the same solution, and the result will be the reduction of the cement, the formation of silicate of soda and carbonate of lime, and the almost perfect cleaning of the diatoms. The former is removable by hot water and frequent washings; the latter, by boiling in nitric acid; while chlorhydric acid dissolves out any sulphate of lime and, besides, bleaches by the abstraction of unattacked metallic stains. The fine siliceous dust, the torment of diatomists, can only be gotten rid of by elutriation, as will presently be shown, and refractory particles or lumps must be left behind in the washings.

If the reader have followed our *proces raisonne*, he will hardly be at a loss to answer the query, "What are we to do with such clay or rock as the *Monterey?*" some specimens of which we have found to be extremely hard or tenacious. In this instance, again, the difficulty presented is the disintegration of the rock without doing injury to the diatoms. We may make the mass very hot and then drop it into cold water, by which many diatoms will be sacrificed; or else we may slightly warm the specimen, drop it into a strong solution of carbonate of potash, and boil for a time, to be ascertained by the breaking down of the original lump. In the same way, carbonate of soda may be employed, with more safety to the forms in request, but with less general success; while the potash, which is more energetic in decomposing the cement, is very destructive, if not carefully watched, of the very objects we seek.

Once reduced to the state of powder, the rules just ennunciated are to be followed.

Before leaving the difficult or troublesome, we feel obliged to notice such guanos as contain sulphate of lime in any quantity, but especially in large proportions. *Algoa Bay guano* (South Africa,) for instance, as furnished us by a reliable person, was found to consist almost wholly of this refractory substance, which required an especial treatment. Being soluble in boiling and hot dilute chlorhydric acid, it was found necessary to boil the Algoa guano in that dilution, and to pour the whole on a filter, whereby the sulphate of lime in solution ran off and deposited on cooling, while the guano residuum was caught by the filter, to be subjected again and again to the same process as long as it contained the salt of lime. The small portion of decalcified guano was next exposed to the action of $NO_5$ and HCl, in the usual way, with the result of securing some beautiful *Actinoptychi* and *Aulacodiscus petersii*.

Recent gatherings, unmixed with sand, mud, or other refractory extraneous substances, are not made to pass through the ordeal of an alkali and so many acids as in the case of a guano, but may be cleaned by the use of one of these agents with the aid of no long-continued heat. Chlorophyll will yield to carbonate of soda, and all possible lime here, to nitric acid; but when we have to deal with very delicate *Amphipleuras* or *Grammatophoras*, marked with almost ghostly lines, we should handle our reagents with gloves, and not boil out those exquisite markings which almost rival the art-ruled bands of Nobert. Maceration for a time may be sufficient; or, if the quantity be small, all phytic substance may be burned away by the heat of a spirit-lamp flame applied beneath a film of mica, on which the "once animated dust" reposes, and on which it may, without change, be mounted in balsam.

It is needless to remind the young operator of the necessity for delicacy in all manipulative procedures, and not least in the washings of pure gatherings, or of those containing the filmy forms. But care is especially to be exercised in the recovery of those most fragile diatoms which are met with in *Barbadoes earth.* Water alone, poured *gently* on this polycystinous deposit, will suffice to float away and waft them to slides ready for their reception. And this may be done in a beaker, so that the supernatant water, rendered milky by diatoms and siliceous dust, yields by elutriation the fairest of results.

*Isolation of Diatoms:*—We have already pointed out the advantage, nay, even the necessity, of preserving the fruits of all cleanings in dilute alcohol, in which they may rest in safety awaiting the separation of the morphous from the amorphous. And we may here add the advice to recommit the diatoms to alcohol finally before mounting, or incidentally, if interruption temporarily arrest the perfect course of the isolation. The methods of Mr. F. Okeden* by decantation, and by whirling in an evaporating capsule or large watch-glass, as suggested by Mr. J. A. Tulk,† we have found to answer every requirement if they be as dexterously managed as they are ingeniously devised. But we would call attention to a point not hitherto noticed, incidental to the decantation process, and which has reference chiefly to the discoid forms. It is this: When the diatoms were nearly or quite free from foreign matters, and beaker glasses were being used in the preparation, we observed that entire disks adhered to the flat bottoms of the vessels. We utilized this knowledge by emptying a beaker, by washing it out quite freely with distilled water, and, finally, by detaching and collecting the absolutely perfect diatoms by means of a soft camel's-hair pencil, well cleaned. In this way we have had excellent success with many gatherings, but with none better than the *Nottingham earth*, as was shown by some of our slides exhibited in Chicago at the reunion of the State Microscopical Society of Illinois.

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*Method of Washing Diatomaceous Earths and Clays; Quarterly Journal of Microscopical Science, vol. iii. p. 158.

†On the Cleaning and Preparing of Diatoms, vol. xi. No. 3. III.

We have now, by whatever process employed, attained the cleaning and separation of the diatoms, and have consigned them to the temporary guardianship of dilute alcohol; but there still remains for us the task of a final preparation of them for mounting. By the plan adopted and suggested by Mr. Okeden they have been "sorted" as to size; yet one washing more is necessary before we can transfer them to the expectant slides. If the diatoms were to be dipped out by a tube directly, and dropped either upon a cover or a slide, the rapid alcoholic evaporation would keep the whole field in agitation, and the objects would eventually group together in drying and materially mar the beauty of the preparation. This defect may be easily remedied by quickly washing out the alcohol; after which the even display of the diatomaceous forms is readily accomplished, especially if we give the end of the slide a fillip with the finger previous to putting it aside to dry spontaneously. At this point the microscopist has the election either of mounting in the *dry way*, or of embalming his tiny treasures in Canada balsam. He may add the balsam drop *au naturel* and gently heat over a spirit flame before applying the cover, or he may omit the evaporation and mount "soft," placing a small screw, for a weight, upon the cover, or he may use balsam thinned by chloroform, or dissolved in absolute alcohol, and filtered as recommended by Dr. Schaeffer, of the Army Medical Museum, and then apply the continuous pressure of a small weight. By the first method the slide will be immediately ready for use when labeled; by the others, a certain number of hours or days must elapse before the margins of the covers will have become securely attached. But the work is done, and the student may now gloat over the things of beauty which he views by the light of science. It is true that he may regret a few forms which have been floated off under the descending cover, but careful manipulation alone will in future prevent this mishap. But how can he imitate the exquisite groupings of the *Diatomaceen-Typn-Platte* of Möller? He may note qual› but he may, with much practice, approximate to the excellence of that wonderfully skillful preparer by arranging his diatoms dry upon a slide or cover previously coated with a thin film of gelatine, and then fixing them by exposure for a moment to the vapor of distilled water. In mounting with balsam the diatoms cannot change position, but the gelatine disappears, and is seen no more forever.

Before closing this paper, perhaps already too long, we deem it germane to the subject to refer to the plan which we have adopted with success in the selection or picking out of particular diatoms. It may not be altogether original, yet it is practical, and may aid the inexperienced.

Nothing is easier than to seize particular diatoms and transfer them to a bottle for future use, or to a slide, provided the field from which we select be rich and clean. Difficulty, however, occurs when forms in any gathering are few and far between. Let such prepared material be spread upon a large slide, covering a space of one inch by two, and let it be filliped as it is set away to dry spontaneously. With a two-third inch objective, search the white field for any diatoms whatever, and, upon finding, encircle each one with a line, made with the point of a match sharpened and moistened, adding near the circle a dot, or cross, or other sign, always appropriated to the same diatom, and of which a tallying record is kept on paper. At leisure one may, without trouble, single out any desired object, pick it off with a fine dampened point of cane (reed), not including the siliceous cuticle, and deposit it, free from injury, in a small drop of distilled water placed in the centre of the slide.

And here we leave our subject, with the remarks that none of the methods proposed can lead to success unless aided by patience, painstaking, the adaptation of means to an end, and by practiced manipulative skill; and that what appears to be present perfection is only to be regarded as one of the widening circles which tend towards, but which never reach, ultimathulan truth.

# *ON THE PREPARATION OF DIATOMACEÆ.

BY PROF. HAMILTON L. SMITH.

The following paper is intended as a supplement to the very excellent article by Christopher Johnston, M. D., in a former number of this journal, under the above heading, and I know of no better guide for the student. What I have to say relates to the rapid preparation, from crude material, where this has been at all carefully gathered, and to a mode of mounting, *invariably on the cover of the slide*, not mentioned by Dr. Johnston, but which has some great advantages. The gatherings should not be dried, but kept moist, in phials with a little creosote to prevent mould. I very much prefer to examine whole frustules, with both valves adherent, or if filamentous, still cohering. And I have many bottles of preparations for mounting which are nearly as clean as though they had been treated with acids. And many of the most interesting preparations which I have were never boiled in acids. Of course, very much depends upon the skill and carefulness of the gatherer, and a little patience and judgment will enable any one to obtain the crude material tolerably pure. Only a few days ago I made a gathering of *Nitzschiæ*, in which I have the frustules almost as free from foreign matter as though they had passed through the most elaborate acid and chlorate of potassa treatment.

Supposing, then, that one has before him a phial which will hold a considerable quantity of water compared with the sediment in it, the latter composed more or less of diatoms. We proceed thus, and if it has stood for some days perfectly undisturbed so much the better. The bottle is twirled rapidly, and the lighter material rising up in the axis will soon diffuse itself throughout the water. Allowing it to settle for two or three seconds, until to the eye the grosser portions have just been deposited, all that remains floating is now poured off into another phial, and it is from this stock that we are to separate the diatoms and sand from the clay and organic matter. The material poured into this second bottle is allowed to settle until the water simply appears milky or cloudy; the time will vary according to the minuteness of the diatoms, and can only be judged of from experience, say one minute, when all that remains floating must be poured off, and thrown away, unless there are very minute forms which it may be desirable to separate. The phial is again to be filled with rain, or distilled water, (hard or lime water should be strictly eschewed,) and again shaken up. As soon as the heaviest deposit touches bottom, the rest should be poured off into a third phial, leaving say about one-fourth the amount behind in the second phial. The third phial will now consist mainly of sand and diatoms, with lighter organic matter and pure clay; the last two can be removed by elutriation; for this purpose, fill the phial No. 3 with water, and after well shaking allow it to settle two to five minutes, pour off and throw away the slightly milky water, and repeat the operation, allowing it to settle a somewhat longer time; the operation may be repeated a third time, when particles, suspended after an interval of eight or ten minutes may be poured off. Often, after the first settling of bottle No. 2, the diatoms will rise more pure in the mass by twirling the bottle than by shaking it up. A little practice and care will enable any one to separate certain diatoms, according to size. I had a gathering of *Pleusosigma spencerii* from Scioto river, O., sent to me, but although it had been chlorated, still when a mounting was made, not more than one or two frustules would be in the field of view, the great mass being either smaller forms, or fine fragments of silex; by careful watching and testing the time when the different sizes would remain suspended, I have made from this a preparation, which will show hundreds where before were scarcely any, and which would never be recognized as the same gathering. Supposing now a trial shows us the diatoms tolerably abundant, the trial being made by heating in the manner presently to be described; the phial is filled with alcohol and water, half and half. Some samples of alcohol leave behind a scum after evaporation, especially noticeable after burning in the mode presently to be described, and water which will leave crystals, or any scum, must be avoided; the beauty of the preparation will largely depend upon being particular in this matter.

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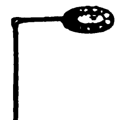
*The Lens. Vol. 2, page 209.

For mounting diatoms I invariably place a drop of the fluid containing them upon the cover, *never on the slide*. The alcohol and water will spread out on the slide, but will remain heaped up on the round cover,like a plain convex lens. I prepare a little stand, represented in the accompaning wood cut, of quite fine wire(so as not to conduct off too much heat) bent at right angles and inserted into a base; the free end is bent into a ring, and upon this ring is placed a square plate of very thin iron (such as is used for the so-called "tintypes" in photography, with the Japan burned off), held in place by bending the corners of the square over the ring, loosely, to allow expansion, without bending when heated; upon this plate the cleaned cover is placed, and then by means of a pipette, a drop of the alcoholic liquid with the diatoms is placed



upon it, and the spirit lamp applied below. The alcohol takes fire and is allowed to burn out; the flame of the lamp is then placed beneath, and the rest gently boiled, the remaining alcohol escaping during this ebullition causes the diatoms, by this very act, to distribute themselves very evenly over the cover, and all matting is effectually prevented. It is better after one perceives that this even distribution has taken place, not to push the heat so as to make large bubbles again, but to slowly evaporate until dry, after which the full power of the flame must be applied until the iron plate and the glass cover is red hot; at first the mass of diatoms, &c., will become black, but as the organic contents and debris burn away there will finally remain only the silex nearly white. I invariably burn in this manner on the cover, even the specimens which have been prepared with acids, for the diatoms thus treated when mounted appear much sharper and cleaner. The amount of heat, if the diatoms are rigidly siliceous, as most of them are, may be the full power of an ordinary alcohol flame continued for some time, but if they are imperfectly siliceous, care must be exercised in the burning.

I invariably use old balsam for mounting, just as bought from the shops, especially if I wish to have a specimen which will bear immediate handling, or be ready to be sent off soon as mounted. Allowing then the cover to cool, while the slide is being cleaned to receive it, I place a drop of the balsam, which must not be fluid, only viscous, on the middle of the slide, and now *with this* pick up the cover from the little stand where it has been heated. The diatoms will be so fastened by the heating, that but few will flow out from under the cover, if any, in the subsequent treatment. I now hold the slide over the flame of the lamp (which should be much smaller than when used for the burning,) until not only all under the cover is a mass of small bubbles, but until very large bubbles, balsam steam, appear; the flame is removed soon as the bubbles are observed all running to one edge. I press down the cover at this place by a mounted pin and start them in the opposite direction. This may seem unnecessary, but long experience shows that this is the better way to get rid of them; during this the slide is held somewhat obliquely, the cover is kept from slipping by the pin, and if all the bubbles do not disappear, then with a very small flame heat is applied just beneath the obstinate ones, the slide being held slanting, and that part upwards where the bubbles are nearest the edge of the cover. The description is longer than the actual process, and the slide when cool is ready for immediate use. Perhaps I am wedded to old ways, but after trial of fluid balsams, without heat, I have always come back to the old way; still, for selected diatoms, some of these preparations of balsam are good. If the diatoms are to be mounted dry, always the best way, if for real study, I make a ring of the zinc white in balsam (sold by the opticians), and which in a moment or two is sufficiently hard to receive the cover, *and never runs in;* after standing an hour or two I give a finishing ring of the same, or the usual black varnish on the outside.

I think any one who will adopt the mode of mounting on the cover, and subsequent heating, as above described, whatever may be the rest of the procedure, will never consent to give up this part, since it effects so even a distribution, and such destruction of residual organic matter, and gives such increased brilliancy to the preparations; sometimes, if the acid has not been thoroughly washed out of acid treated specimens, snappy explosions will occur when the alcoholic mixture is heated; of course, the remedy is to pour off, and replace with pure water and alcohol.

# VII.

# OXIDE OF MANGANESE.

N. H. WINCHELL.

It was through the persevering efforts of Mr. J. N. Stacy that this ore has been discovered at and near Monticello, in Wright county. He first noticed a black substance along the bank of the Mississippi, overlying the gray boulder clay and underlying a thick stratum of gravel and sand. This black substance appeared to be brought to the surface and to be distributed more or less on the slope for a distance of several rods, through the action of spring water which constantly oozed from the bluff at about the same level. On having an analysis made Prof. Dodge reported the following May 26, 1891:

| | |
|---|---|
| Sand and clay | 4 98 |
| Carb. lime | 6.86 |
| Carb. magnesia | .85 |
| Oxide of iron | .51 |
| Black oxide of manganese | 79.83 |
| Phosphorus | .09 |
| Sulphur | .01 |
| Water of hydration and organic matter | 6.87 |
| | 100.00 |

Subsequently considerable examination was made in some of the bogs in the vicinity further west and north, so situated as to presumably constitute the main reservoir, notably for the water seen at the river bank, but also for the principal deposit of the manganese oxide, and, although several analyses were made of a ferruginous sub-peat deposit, no manganese oxide of sufficient purity was found at that time. Several shipments of a few tons each were made from the orignial locality, and the excellence of the product stimulated further exploration. The result has been to demonstrate that in several places a bog manganese exists in considerable quantity, more or less associated with bog iron ore, constituting an ore which is valuable for many uses in the arts. Analyses show manganese oxide ranging from almost nothing to ten per cent., and iron oxide to thirty and forty per cent., with the usual varying accompaniments of carbonate of lime, silica and organic matter. Such an ore is widely distributed through that part of the state, and it is very probable that, if exploration be continued, larger deposits of as great purity as that which is found in limited amount by the bank of the river, and analyzed as above, will be brought to light.

It has also been noticed that some of the iron ore deposits lately discovered on the Mesabi range are accompanied by a noteworthy percentage of manganese oxide, promising to be more valuable as manganese ores than as iron ores.

## MUSEUM

### SPECIMENS REGISTERED IN THE GENERAL

| Serial No. | Obtained. |  | Name. | Number of specimens |
|---|---|---|---|---|
|  | When. | Whence. |  |  |
| 8101 | Oct., 1892 | Donation. | Proboscina tumulosa Ulrich |  |
| 8102 | " | " | " frondosa Nicholson |  |
| 8103 | " | " | Mitoclema (?) mundulum Ulrich |  |
| 8104 | " | " | Rhinidictya neglecta Ulrich |  |
| 8105 | " | " | " minima Ulrich |  |
| 8106 | " | " | " " var. modesta Ulrich |  |
| 8107 | " | " | Pachydictya pumila Ulrich |  |
| 8108 | " | " | Arthropora bifurcata Ulrich | 2 |
| 8109 | " | " | " reversa Ulrich | 3 |
| 8110 | " | " | Stictoporella dumosa Ulrich | Num. |
| 8111 | " | " | Nematopora granosa Ulrich |  |
| 8112 | " | " | Helopora mucronata Ulrich |  |
| 8113 | " | " | " harrisi James |  |
| 8114 | " | " | Arthroclema striatum Ulrich | 1 |
| 8115 | " | " | " cornutum Ulrich | 1 |
| 8116 | " | " | " armatum Ulrich |  |
| 8117 | " | " | Callopora goodhuensis Ulrich | 6 |
| 8118 | " | " | " dumalis Ulrich | Num. |
| 8119 | " | " | " undulata Ulrich | 4 |
| 8120 | " | " | " pulchella Ulrich | 3 |
| 8121 | " | " | " pulchella var. persimilis Ulrich | 2 |
| 8122 | " | " | Homotrypa separata Ulrich | 2 |
| 8123 | " | " | " tuberculata Ulrich | 4 |
| 8124 | " | " | Homotrypella ovata Ulrich | 4 |
| 8125 | " | " | " rustica Ulrich |  |
| 8126 | " | " | Aspidopora elegantula Ulrich | 1 |
| 8127 | " | " | Mesotrypa spinosa Ulrich | 2 |
| 8128 | July, 1891 | Geol. Survey | " quebecensis Ulrich | 5 |
| 8129 | Oct., 1892 | Donation | Eridotrypa exigua Ulrich | 5 |
| [illegible] | " | " | Constellaria varia Ulrich | 2 |
| [illegible] | " | " | Nicholsonella pulchra Ulrich | 1 |
| [illegible] | " | " | Leptotrypa [illegible] Ulrich | 1 |
| [illegible] | " | " | Nematopora ovalis Ulrich |  |
| [illegible] | " | " | Batostoma [illegible] Ulrich | 3 |
| [illegible] | " | " | " [illegible] Ulrich | 1 |
| [illegible] | " | " | " [illegible] Ulrich | 3 |
| [illegible] | " | " | " " var. [illegible] Ulrich |  |
| [illegible] | July, [illegible] | Geol. Survey | Leptaena unicostata Meek & Worthen | 1 |
| [illegible] | " | " | " " | 3 |
| [illegible] | Aug., [illegible] | " | " " | [illegible] |
| [illegible] | [illegible] | " | " " | 3 |
| [illegible] | " | " | " [illegible] Winchell & Schuchert | 1 |
| [illegible] | " | [illegible] | Rafinesquina [illegible] | 12 |
| [illegible] | " | " | [illegible] | 5 |
| [illegible] | [illegible] | " | " " var. [illegible] Sard. | Num. |
| [illegible] | " | " | " " | 5 |
| [illegible] | " | " | " " | Num. |
| [illegible] | " | " | " " | 6 |
| [illegible] | " | [illegible] | " " | 1 |
| [illegible] | " | " | [illegible] " | 5 |
| [illegible] | " | " | " [illegible] | [illegible] |
| [illegible] | " | " | [illegible] | 1 |
| [illegible] | [illegible] | [illegible] | " " | 5 |
| [illegible] | [illegible] | " | " " | 3 |
| [illegible] | [illegible] | " | " [illegible] Meek | [illegible] |
| [illegible] | [illegible] | " | [illegible] | [illegible] |
| [illegible] | " | " | " [illegible] | [illegible] |
| [illegible] | " | " | " " | 3 |
| [illegible] | Aug., [illegible] | " | " | 4 |
| [illegible] | " | " | [illegible] | 4 |
| [illegible] | " | " | [illegible] | 5 |
| [illegible] | [illegible] | " | " " | 5 |
| [illegible] | [illegible] | " | " | [illegible] |
| [illegible] | [illegible] | " | [illegible] | 3 |
| [illegible] | [illegible] | " | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | " | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | " | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |

## ADDITIONS.

### MUSEUM SINCE THE LAST REPORT.

| Locality. | Formation. | Collector and Remarks. |
|---|---|---|
| Cannon Falls, Minn | Tr'nt'n shales | E. O. Ulrich. |
| Cincinnati, Ohio | Hudson River | “ |
| Cannon Falls, Minn | Trent. shales | “ |
| Near Danville, Ky | Trenton | “ |
| Cannon Falls, Minn | Galena shales | “ |
| “ | “ | “ |
| “ | “ | “ |
| St. Paul, Minn | Trenton | “ |
| “ | Galena shales | “ |
| “ | Trenton | “ |
| Near Cannon Falls, Minn | Galena shales | “ |
| “ | “ | “ |
| Waynesville, Ohio | Hudson River | “ |
| Minneapolis, Minn | Trenton | “ |
| “ | “ | “ |
| Near Cannon Falls, Minn | Galena shales | “ |
| “ | “ | “ |
| St. Paul, Minn | Trenton | “ |
| “ | “ | “ |
| “ | “ | “ |
| Near Cannon Falls, Minn | “ | “ |
| Minneapolis, Minn | “ | “ |
| Near Cannon Falls, Minn | “ | “ |
| “ | Galena shales | “ |
| Richmond, Ind | Hudson River | “ |
| St. Paul, Minn | Galena shales | “ |
| Minneapolis, Minn | Trenton | “ |
| Decorah, Iowa | Galena shales | C. Schuchert. |
| Near Cannon Falls, Minn | “ | E. O. Ulrich. |
| “ | “ | “ |
| Murfreesboro, Tenn | Trenton | “ |
| Minneapolis, Minn | “ | “ |
| Near Cannon Falls, Minn | Galena shales | “ |
| “ | Trenton | “ |
| Minneapolis, Minn | “ | “ |
| St. Paul, Minn | “ | “ |
| “ | “ | “ |
| Near Granger, Minn | Hudson River | Scofield & Schuchert. |
| Graf, Iowa | “ | C. Schuchert. |
| Spring Valley, Minn | “ | Scofield & Schuchert. |
| Iron Ridge, Wis | “ | C. Schuchert. |
| West Side, St. Paul, Minn | Trent. shales | “ |
| McGregor, Iowa | “ | “ |
| Decorah, Iowa | “ | “ |
| Mineral Point, Wis | Upper Buff | “ |
| Rockton, Ill | L. blue beds | “ |
| Janesville, Wis | “ | “ |
| 4 miles north of Beloit, Wis | “ | “ |
| Preston, Minn | Trent. shales | Scofield & Schuchert. |
| 12 m. S. of Cannon Falls, Minn | Galena shales | “ |
| “ | “ | “ |
| Preston, Minn | Trent. shales | “ |
| 6 mi. S. of Cannon Falls, Minn. | Galena shales | “ |
| Mineral Point, Wis | Upper buff | C. Schuchert. |
| Spring Valley, Minn | Hudson River | Scofield & Schuchert. |
| Iron Ridge, Wis | “ | C. Schuchert. |
| Oshkosh, Wis | Galena | “ |
| Dubuque, Iowa | “ | “ |
| Weisebach's dam nr. Spring Val. [Minn | “ | Scofield & Schuchert. |
| Near Hamilton, Minn | Top of Galena | “ |
| Mantorville, Minn | Galena | “ |
| Near Granger, Minn | Hudson River | “ |
| Bellville, N Y | Trenton |  |
| 3 mi S of Cannon Falls, Minn | Galena | Scofield & Schuchert. 50 ft. above base. |
| 3 & 5 m. S. of Cannon Falls, Minn. | “ | “ “ |
| Mantorville, Minn | “ | “ |
| Dodgeville, Wis | Trenton | C. Schuchert. |
| McGregor, Iowa | Trent. shales | “ |
| Decorah, Iowa | “ | “ |
| Mineral Point, Wis | Trenton | “ |
| 4 mi. N. of Beloit, Wis | L blue beds | “ |
| Janesville, Wis | “ | “ |
| Mineral Point, Wis | “ | “ |
| Rockton, Ill | “ | “ |

## MUSEUM

### SPECIMENS REGISTERED IN THE

| Serial No | Obtained. | | Name. | Number of specimens |
|---|---|---|---|---|
| | When. | Whence. | | |
| 8175 | Aug., 1891. | Geol. survey... | Strophomena incurvata Sheppard ......... | 9 |
| 8176 | " | " ... | " " " ........... | 11 |
| 8177 | " | " .... | " " " ........... | 2 |
| 8178 | " | " .... | " " " ........... | 6 |
| 8179 | July, 1891. | " .... | " trentonensis Winchell & Schuchert | 2 |
| 8180 | " | " .... | " winchelli Hall ............ | 2 |
| 8181 | Aug., 1891. | " .... | " trentonensis (?) Win. & Schuchert. | 3 |
| 8182 | " | " .... | " trentonensis Winchell & Schuchert | 7 |
| 8183 | " | " .... | " " | 4 |
| 8184 | July, 1891. | " ... | " rugosa Rafinesque. ............... | 12 |
| 8187 | Aug., 1891. | " .... | " fluctuosa Billings.................. | 13 |
| 8188 | " | " .... | " " | 3 |
| 8189 | " | " .... | " trilobata Owens...................... | 3 |
| 8190 | " | " .... | " " | 2 |
| 8191 | July, 1891. | " .... | " planodorsata Winch'll & Schuchert | 1 |
| 8192 | Aug., 1891. | " .... | " billingsi Winchell & Schuchert .... | 2 |
| 8193 | " | " .... | " scofieldi Winchell & Schuchert..... | 11 |
| 8194 | " | " .... | " " | 2 |
| 8195 | July, 1891. | " .... | " " | 1 |
| 8196 | Aug., 1891. | " .... | Rhynchotrema capax Conrad................ | 14 |
| 8197 | July, 1891 | " .... | " " | 10 |
| 8198 | " | " .... | " " | 22 |
| 8199 | " | " .... | " " | 8 |
| 8200 | " | " .... | " perlamellosa Whitfield........ | 2 |
| 8201 | " | " .... | " anticostiensis Billings ........ | 16 |
| 8202 | " | " .... | " " | 10 |
| 8203 | " | " .... | " " | 4 |
| 8204 | " | Donation ... | " ainsliei Winchell ............. | 3 |
| 8205 | Aug., 1891 | Geol. survey... | " " | 1 |
| 8206 | " | " .... | " " | 5 |
| 8207 | July, 1891. | " .. | " " | 1 |
| 8208 | Oct., 1892. | Donation ...... | Escharopora confluens Ulrich...... ....... | |
| 8209 | Aug., 1891 | Geol. survey... | Rhynchotrema inaequivalis Castelnau..... | 4 |
| 8210 | " | " .... | " " | 18 |
| 8211 | " | " ... | " " | 12 |
| 8212 | July, 1891. | " .... | " " | 3 |
| 8213 | " | " .... | " " | 10 |
| 8214 | " | " .... | " " | 7 |
| 8215 | " | " .... | " " | 4 |
| 8216 | " | " ... | " " | 4 |
| 8217 | " | " .... | " " | Num. |
| 8218 | Aug., 1891. | " .... | " " | " |
| 8219 | " | " .... | " " | 5 |
| 8220 | " | " .... | Zygospira recurvirostris Hall var. Minnesotensis W & S | Num. |
| 8221 | " | " .... | " " | 10 |
| 8222 | " | " .... | " " | 34 |
| 8223 | July, 1891. | " .... | " " | 3 |
| 8224 | Dec., 1891.. | Donation ..... | " " | Num. |
| 8225 | " | " ...... | Raufella palmipes Ulrich..................... | 1 |
| 8226 | July, 1891 | Geol. survey. | Strophomena winchelli Hall.... ..... ..... | 1 |
| 8227 | Aug., 1891 | " .... | Zygospira uphami Winchell & Schuchert.. | 10 |
| 8228 | " | " .... | " modesta Say Hall.... ......... | 1 |
| 8229 | " | " | Anastrophia [illegible] Win. & Schuchert | 28 |
| 8230 | " | " ... | " hemiplicata var. rotunda W & S | 1 |
| 8231 | " | " .... | " hemiplicata Hall......... ..... | 5 |
| 8232 | " | " ... | " " | 2 |
| 8233 | " | " .... | " " | 2 |
| 8234 | " | " .... | " " | 2 |
| 8235 | " | " ... | " " | 3 |
| 8237 | Jan., 1892. | Donation ...... | Hallina saffordi Winchell & Schuchert.... | 4 |
| 8238 | Aug., 1891. | Geol. survey . | " [illegible] Winchell & Schuchert. | 3 |
| 8239 | " | " .. | " [illegible] Winchell & Schuchert. | Num. |
| 8240 | Feb., 1892. | Donation ..... | [illegible] W. & Schuchert.. | 1 |
| 8241 | Sept., 1892. | Exchange .... | [illegible] spiculata ...................... | 5 |
| 8242 | " | " .... | [illegible] ..................... | 1 |
| 8243 | " | " .. | [illegible] ........................ | 7 |
| 8244 | " | " ...... | [illegible] ..................... | 3 |
| 8245 | " | " .... | [illegible] ..................... | 3 |
| 8246 | " | " ...... | [illegible] ..................... | 5 |
| 8247 | " | " ...... | [illegible] ..................... | 1 |
| 8248 | " | " | [illegible] ..................... | 5 |
| 8249 | " | " | [illegible] ..................... | 1 |
| 8250 | " | " .. | [illegible] ..................... | 1 |
| 8251 | " | " . | [illegible] ..................... | 1 |

ADDITIONS—*Continued*.

GENERAL MUSEUM SINCE THE LAST REPORT.

| Locality. | Formation. | Collector and Remarks. |
|---|---|---|
| Preston, Minn | Tr'nt'n shales | Scofield & Schuchert. |
| Fountain, Minn | " | " |
| St. Paul, Minn | " | C. Schuchert. |
| Minneapolis, Minn | " | J. C. Kassube. |
| 4 miles N. of Beloit, Wis | L. blue beds.. | C. Schuchert. |
| Janesville, Wis | " | " |
| Kenyon, Minn | Galena shales | W. H. Scofield. |
| 6 miles S. of Cannon Falls, Minn | Top Tr. shales | Scofield & Schuchert. |
| 2 miles S. of Cannon Falls, Minn | Tr'nt'n shales | " |
| Iron Ridge, Wis | Hudson River | C. Schuchert. |
| Spring Valley, Minn | " | Scofield & Schuchert. |
| Near Granger, Minn | " | " |
| Mantorville, Minn | Galena | " |
| 3 miles S. of Cannon Falls, Minn | " | " 50 ft. above base. |
| Iron Ridge, Wis | Hudson River | C. Schuchert. |
| Fountain, Minn | Galena shales | Scofield & Schuchert. |
| 2 miles S. of Cannon Falls, Minn | " | " |
| St. Paul. Minn | Top Tr. shales | C. Schuchert. |
| 4 miles N. of Beloit, Minn | L. blue beds. | " |
| Spring Valley, Minn | Hudson River | Scofield & Schuchert. |
| Graf, Iowa | " | C. Schuchert. |
| Iron Ridge, Wis | " | " |
| Near Clifton, Wis | " | " |
| Iron Ridge, Wis | " | " |
| Graf. Iowa | " | " |
| Iron Ridge, Wis | " | " |
| Near Clifton, Wis | " | " |
| Rochester, Minn | Tr'nt'n shales | N. Ainslee. |
| Preston, Minn | " | Scofield & Schuchert. |
| Chatfield, Minn | " | " |
| McGregor, Iowa | " | C. Schuchert. |
| Minneapolis, Minn | " | E. O. Ulrich. |
| 10 mil's S. of Cannon Falls, Minn | Galena shales | Scofield & Schuchert, 50 feet above base. |
| Warsaw, Minn | " | W. H. Scofield. |
| Fountain, Minn | " | Scofield & Schuchert. |
| Neenah, Wis | Galena | C. Schuchert. |
| Oshkosh, Wis | " | " |
| Janesville, Wis | L. blue beds.. | " |
| Mineral Point. Wis | " | " |
| McGregor. Iowa | Tr'nt'n shales | " |
| Decorah, Iowa | " | " |
| 6 miles S. of Cannon Falls, Minn | Galena shales | Scofield & Schuchert. |
| Warsaw. Minn | " | " |
| 2 miles S. of Cannon Falls, Minn | " | " |
| 6 miles S. of Cannon Falls, Minn | " | " |
| Near Fountain, Minn | Tr'nt'n shales | " |
| Oshkosh, Wis | Galena | C. Schuchert. [growth. |
| St. Paul. Minn | Tr'nt'n shales | " Specimens in all stages of |
| Minneapolis Minn | " | " Lake street bridge. |
| Oshkosh, Wis | Galena | " |
| Weisebachs dam, n'r Spr'g Val'y | " | Scofield & Schuchert. |
| Spring Valley, Minn | Hudson River | " |
| 6 miles S. of Cannon Falls, Minn | Galena | " |
| 5 miles S. of Cannon Falls. Minn | " | " |
| 12 miles S. of Cannon Falls, Minn | " | " |
| Weisbach's dam | " | " Near Spring Valley. |
| Near Fountain, Minn | " | " |
| Preston. Iowa | " | " |
| Decorah, Iowa | " | C. Schuchert. |
| Lebanon, Tenn | Glade l'm'st'n | " |
| Decorah. Iowa | Tr'nt'n l'mstn | " |
| Near Fountain, Minn | " | Scofield & Schuchert. |
| Near Cannon Falls, Minn | Tr'nt'n shales | C. Schuchert. |
| Richmond, Ohio | L. coal Meas.. | Sam Huston. |
| " | " | " |
| " | " | " |
| " | " | " |
| " | " | " |
| " | " | " |
| " | L. b'r'en co'l M | " |
| " | " | " |
| Linton, Ohio | L. coal Meas.. | " |
| " | " | " |
| " | " | " |

## MUSEUM

### SPECIMENS REGISTERED IN THE

| Serial No. | Obtained: When. | Obtained: Whence. | Name. | Number of specimens. |
|---|---|---|---|---|
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |

## ADDITIONS.—*Continued.*

### GENERAL MUSEUM SINCE THE LAST REPORT.

| Locality. | Formation. | Collector and remarks. |
|---|---|---|
| Lebanon, Ohio | Glade l'mst'n. | C. Schuchert. |
| Rock Island, Ill | Hamilton | J. A. Udden. |
| " " | " | " |
| " " | " | " |
| " " | " | " |
| " " | " | " |
| " " | " | " |
| " " | " | " |
| " " | " | " |
| " " | " | " |
| " " | " | " |
| " " | " | " |
| " " | " | " |
| " " | Corniferous | " |
| " " | Hamilton | " |
| " " | Corniferous | " |
| " " | " | " |
| " " | " | " |
| " " | " | " |
| " " | " | " |
| " " | Hamilton | " |
| Mineral Point, Wis | L. blue beds | C. Schuchert. |
| Reckton, Ill | U. buff beds | " |
| Rockdell, P. O., Minn | Galena. | Scofield and Schuchert. |
| Janesville, Wis | L. blue beds | C. Schuchert. |
| " | " | " |
| Near Fountain, Minn | Galena shales | Scofield and Schuchert. |
| " " | Trenton " | " " |
| Decorah, Iowa | " " | C. Schuchert. |
| Warsaw, Minn | Galena " | W H. Scofield. |
| Mineral Point, Wis. | L. blue beds | C. Schuchert. |
| Near Rochester, Minn | Galena | W. H. Schofield. |
| Preston, Minn | L. Galena | Scofield and Schuchert. |
| Cannon Falls, Minn | Trenton limestone | W. H. Scofield. |
| Mineral Point, Wis | L. blue beds | C. Schuchert. |
| McGregor, Iowa | Trenton sh'l's | " |
| Janesville, Wis. | L. blue beds | " |
| Mineral Point, Wis | " | " |
| Stewartsville, Minn | Mid'le Galena | Scofield and Schuchert. of Stewartsville. The largest specimen donated by F. L. Wood. |
| " " | " | |
| Mantorville, Minn | " | Scofield and Schuchert. |
| Pleasant Grove, Minn | " | " " |
| Near Fountain, Minn | Trenton sh'l's | " |
| Mineral Point, Wis | L. blue beds | C. Schuchert. |
| Minneapolis, Minn | Trenton limestone | H. V. Winchell. |
| Janesville, Wis | Lower bluff | C. Schuchert. |
| Preston, Wis | Trenton sh'l's | Scofield and Schuchert. |
| Minneapolis, Minn | Trenton limestone | |
| Janesville, Wis | L. blue beds | C. Schuchert. |
| Minneapolis, Minn | Trenton limestone | H. V Winchell. |
| Preston, Minn | Trenton sh'l's | Scofield and Schuchert. |
| " | " | " " |
| Minneapolis, Minn | " | E. O Ulrich. |
| " | | |
| 2 m. S. E. of Cannon Falls, Minn. | Galena shales | E. O. Ulrich. |
| Near Fountain, Minn | Trenton | " |
| St. Paul, Minn | " | " |
| Minneapolis, Minn | | Wm. Howling. (5675). |
| | | C. L Herrick. (5108). |
| | | H. V. Winchell. (5063). |
| " | | |
| " | | C. L. Herrick. (773). |
| " | | (6867). |
| Kenyon, Minn | | N. H. Winchell. |
| Lime City, Minn | | " |
| Decorah, Iowa | | C. Schuchert. |
| Granger, Minn | L. Hudson R. | " |

## MUSEUM

### SPECIMENS REGISTERED IN THE

| Serial No. | Obtained. | | Name. | Number of specimens |
|---|---|---|---|---|
| | When. | Whence. | | |
| 8393 | ........... | ..... ... ........ | Fusispira nobilis Ulrich and Scofield....... | .......... |
| 8394 | ........... | ...... .......... | " vitata Hall........................ | 1 |
| 8395 | ........... | ................. | " vaticina Ulrich and Scofield..... | 1 |
| 8396 | ........... | .. .. ........... | " convexa Ulrich and Scofield..... | .......... |
| 8427 | Sept., 1880 | Geol. Survey... | Trochonema umbilicatum Hall............ | .......... |
| 8428 | 1884 | By purchase... | " beachi Whitfield............. | ..... .... |
| 8429 | Oct., 1892 | Donation........ | Pachydictya occidentalis Ulrich........... | 4 |
| 8430 | Oct., 1892 | Donation ....... | Rhinidictya paupera Ulrich................ | 5 |
| 8431 | " | " ....... | Escharopora limitaris Ulrich .......... .... | 3 |
| 8432 | " | " ....... | Callopora ampla Ulrich .................... | 4 |
| 8433 | " | " ....... | Callopora crenulata Ulrich :................ | 2 |
| 8436 | Aug., 1891 | " ....... | Asaphus gigas DeKay ...................... | 1 |
| 8437 | " | " ....... | Asaphus megistus Locke .................... | 1 |
| 8438 | " | " ....... | " " " ........ ......... | 1 |
| 8439 | July, 1891 | Geol. survey... | Lingula modesta Ulrich .................... | 3 |
| 8440 | " | " ... | Maclurea cuneata Whitfield ........ ....... | 22 |
| 8441 | ....... .... | " ... | " " " ............... | 1 |

ADDITIONS.—*Continued.*

GENERAL MUSEUM SINCE THE LAST REPORT.

| Locality. | Formation. | Collector and remarks. |
|---|---|---|
| Decorah, Iowa |  | C. Schuchert. |
| Fountain, Minn |  | Scofield and Schuchert. |
| Petit's mill, Mantorville, Minn. |  | N. H. Winchell. |
| Decorah, Iowa |  | C. Schuchert. |
| Lime City, Minn |  | N. H. Winchell. (4104). |
| Minneapolis, Minn |  | Wm. Howling. (5675). |
| St. Paul, Minn | Trenton |  |
| St. Paul, Minn | Trenton | E. O. Ulrich. |
| Minneapolis, Minn | " | " |
| Near Cannon Falls, Minn | Galena shales | " |
| St. Paul, Minn | Trenton | " [natural mould. |
| Granger, Minn. | Hudson river | R. H. Hesse, gutta-percha impression of |
| " " | " | " gutta-perc. imp. of nat. mould |
| " " | " | " |
| " " | L. Hudson R. | Scofield and Schuchert. |
| Lime City, Minn |  | N. H. Winchell. |
| " " |  | " |

# Additions to the Library Since the Report for 1890.

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[illegible]

[illegible]

[illegible]

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# PUBLICATIONS OF THE GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA.

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The First Annual Report for 1872. 112 pp., 8vo with a colored map of the state. By *N. H. Winchell.* Published in the Regents' Report for 1872; contains a sketch of the geology of the state, as then known, and a list of earlier reports. Second edition (1884) identical.

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The Eighth Annual Report, for 1879. 183 pp., 8vo.; one plate (Castoroides). By *N. H. Winchell;* Containing a statement of the methods of Microscopic Lithology; a discussion of the Cupriferous Series in Minnesota, and descriptions of new species of brachiopoda from the Trenton and Hudson river formations; with reports on the Geology of Central and Western Minnesota, by *Warren Upham;* on the Lake Superior region, by *C. W. Hall;* lists of birds and of plants from Lake

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Superior, by *Thomas S. Roberts;* Chemical Analyses, by *S. F. Peckham;* Report by *P. L. Hatch;* and four Appendixes. Also in the Regents' Report for 1879 and 1880. Out of print.

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THE TENTH ANNUAL REPORT, FOR 1881. 254 pp., 8vo.; with ten wood cut illustrations and fifteen plates. By *N. H. Winchell.* Containing field descriptions of about four hundred rock samples, and notes on their geological relations, continued from the last report. the Potsdam sandstone; typical thin sections of the rocks of the Cupriferous series; and the deep well at the "C" Washburn mill, Minneapolis; with Geological notes, by *J. H. Kloos;* Chemical Analyses, by *J. A. Dodge;* and papers on the Crustacea of the fresh waters of Minnesota; eleven plates, by *C. L. Herrick.* Also in the Regents' Report for 1881 and 1882.

THE ELEVENTH ANNUAL REPORT, FOR 1882. 219 pp., 8vo.; with three wood cut illustrations and one plate. By *N. H. Winchell.* Containing a report on the Mineralogy of Minnesota, and a note on the age of the rocks of the Mesabi and Vermilion iron districts; with papers on the crystalline rocks of Minnesota, by *A. Streng* and *J. H. Kloos;* on rock outcrops in Central Minnesota and on Lake Agassiz, by *Warren Upham;* on the iron reigon of Northern Minnesota, by *Albert H. Chester;* Chemical Analyses, by *J. A. Dodge;* and an Appendix containing Minnesota Laws relating to Mines and Mining, abstracted by *C. L. Herrick.* Also in the Regents' Report for 1881 and 1882.

THE TWELFTH ANNUAL REPORT, FOR 1883. Summary report, containing palæontological notes and a paper on the comparative strength of Minnesota and New England granites, twenty-six pages, by *N. H. Winchell;* final report on the Crustacea of Minnesota, included in the orders of Cladocera and Copepoda, 192 pages and 30 plates by *C. L. Herrick*, and a catalogue of the flora of Minnesota, 193 pages, with one map showing the forest distribution, by *Warren Upham.* Also in the Regents' Report for 1883 and 1884.

THE THIRTEENTH ANNUAL REPORT, FOR 1884. 196 pp. Geological reconnoisances the Vermilion iron ores, the crystalline rocks of Minnesota and of the Northwest, the Humboldt salt-well in Kittson county, records of various deep wells in the state, fossils from the red quartzyte at Pipestone, reports on the New Orleans Exposition and on the General Museum, by *N H. Winchell;* Geology of Minnehaha County, Dakota, by *Warren Upham;* Chemical report, by *Prof. Jas. A. Dodge;* Minnesota geographical names derived from the Dakota language, by *Prof. A. W. Williamson;* insects injurious to the cabbage, by *O. W. Oestlund;* Geological notes in Blue Earth county, by *Prof. A.*

*F. Bechdolt;* and on a fossil elephant from Stockton, by *Prof. John Holzinger;* papers on the Cretaceous fossils in the boulder clays in the Northwest, by *George M. Dawson* and by *Woodward* and *Thomas;* and notes on the Mammals of Big Stone lake and vicinity, by *C. L. Herrick*.

THE FOURTEENTH ANNUAL REPORT, FOR 1885. 354 pp.; two plates of fossils and two wood cuts. By *N. H. Winchell.* Containing summary report, notes on some deep wells in Minnesota, descriptions of four new species of fossils, a supposed natural alloy of copper and silver from the north shore of Lake Superior, and revision of the stratigraphy of the Cambrian in Minnesota, with the following papers by assistants, viz: List of the Aphididæ of Minnesota, with descriptions of some new species by *O. W. Oestlund;* Report on the Lower Silurian Bryozoa, with preliminary descriptions of some new species, by *E. O. Ulrich;* Conchological notes, by *U. S. Grant;* Bibliography of the Foraminifera, recent and fossil, by *Anthony Woodward.*

THE FIFTEENTH ANNUAL REPORT, FOR 1886. 493 pp., 8vo.; 120 diagram illustrations and sketches in the text, and two colored maps; embracing reports on observations on the crystalline rocks in the northeastern part of the state, by *Alexander Winchell, N. H. Winchell* and *H. V. Winchell;* Chemical report by *Prof. J. A. Dodge;* additional railroad elevations by *N. H. Winchell;* list of Minnesota geographical names derived from the Chippewa language, by *Rev. J. A. Gilfillan,* and notes on Illæni, describing three new species, by *Aug. F. Foerste.* Also as supplement II of the Regents' Report for 1887–1888.

THE SIXTEENTH ANNUAL REPORT, FOR 1887. 504 pp. 8vo.; two plates and 83 other illustrations. Contains reports on the original Huronian area, the Marquette iron region, on the Gogebic and Penokee iron-bearing rocks, on the formations of northeastern Minnesota (including the physicial aspects, vegetation, quadrupeds and other vertebrates), the geology of the region northwest from Vermilion lake to Rainy lake and of the Little and Big Fork rivers; also notes on the Molluscan fauna of Minnesota.

THE SEVENTEENTH ANNUAL REPORT, FOR 1888. pp. 280, 8vo.; ten text illustrations. Contains: Report of *N. H. Winchell,* the crystalline rocks of Minnesota, a general report of progress made in the study of their field relations, with a bibliography of recent works on the crystalline rocks; report of *H. V. Winchell,* field observations in the iron regions; report of *Uly. S. Grant,* geological observations in northeastern Minnesota.

THE EIGHTEENTH ANNUAL REPORT, FOR 1889. Report of further field observations in the regions of the crystalline rocks of the state and in the area of the original Huronian, by *N. H. Winchell,* and a review of American opinion on the older rocks, by *Alexander Winchell.* Octavo, pp. 234.

THE NINETEENTH ANNUAL REPORT, FOR 1890. 8vo. pp. 255, with illustrations. Translation of Boricky's elements of a new Chemico-microscopic method of analysis of rocks and minerals, and of Kloos' Geognostic and Geographical observations in Minnesota in 1877, by *N. H. Winchell,* chemical report by *Prof. Dodge,* the woods of Minnesota, by *H. B. Ayres*; museum and library additions, list of meteorites in the museum, petrography and geology of the Akeley lake region, *W. S. Bayley,* New Lower Silurian Lamellibranchiata, *E. O. Ulrich.*

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